"Distribution and Taxonomy of family Sternoptychidae and Photichthyidae and biology of the genus *Vinciguerria* (Photichthyidae) in the west coast of the Indian EEZ"

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CERTIFICATE

This is to certify that the thesis entitled "Distribution and Taxonomy of family Sternoptychidae and Photichthyidae and biology of the genus *Vinciguerria* (Photichthyidae) in the west coast of the Indian EEZ " submitted by Miss.Vimala Persis Thyagaraj for the award of Degree of Doctor of Philosophy in Marine Biology of Karnatak University is based on the results of experiments carried out by her under my supervision. The thesis or a part thereof has not been previously presented for any Diploma or Degree.

Kusuma Neelakantan

[Kusuma Neelakantan]

Dedicated

to

my Parents

who

through their love have led me

to

the Greatest love of all

'Love of Jesus'

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VPersis

VIMALA PERSIS THYAGARAJ.

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Chapter - I

Introduction

1. INTRODUCTION

1.1. General Introduction

The oceanic environment is the biggest biome on earth and its biota plays a significant role in global, biological and chemical cycles. (Lawrence and Katherine, 1995). Most of the world's oceans with the exception of the Arctic and Antarctic and possibly parts of the Central Pacific have a region at depth that reflects or scatters sound. This is known as the Deep scattering layer (DSL). The Deep scattering layers in the oceans were first recognized in 1942. The DSL is a layer of living organisms ranging from about microscopic zooplankton, shrimps, mesopelagic fishes and cephalopods that prey on one another. This layer migrates vertically in the water column depending on light intensity and occurs at depths between 230-800m during the day and 50-100m depth during night. The DSL is an important ecosystem of the world oceans and supports a wide assembly of zooplankton, macro and micro nekton. The availability abundance and vertical migration of several species of epipelagic and mesopelagic fishes are influenced or controlled by the occurrence and quantity of favorite food components in the DSL (Menon and Prabha devi, 1989).

Micro nektonic organisms like pelagic shrimps, swarming crabs, cephalopods and finfishes contribute substantially to the richness of the DSL at all geographic and bathymetric realms. Finfishes belonging to many taxa together constituted 54% of the total DSL numerical biomass, whereas in the micro nektonic catch of IKMT (Isaacs-Kidd Midwater Trawl), finfishes formed 91.8% (93%in night and 90% in day hauls). A variety of juvenile and sub adults of epipelagic and mesopelagic layers dominated the fish biomass. The important groups that occurred frequently in the IKMT catches were the Photichthyidae (*Vinciguerria sp.*), Myctophidae, Sternoptychidae, Gonostomatidae etc., among others. (Menon, 1990)

The DSL studies have also helped in bioenergetics. These vertically migrating fish are good energy sources and are widespread and important in fish diets. (Childress *et al.*, 1980). Haedrich and Merett (1992) showed that most demersal deep sea species are wide foragers or scavengers which exploit allocthonous food sources from migrating fauna and especially among species of small adult size at abyssal depths.

The potential and prospects for exploitation of the mesopelagic fishes from the oceanic realm is gaining importance in the light of the present stagnating trends in fish production and the increasing demand to meet the per capita seafood. Among the many mesopelagic fauna the fishes belonging to the family Sternoptychidae and Photichthyidae are common in the DSL and are caught frequently at night in the surface net. Being important forage fishes a study on their taxonomy, abundance and distribution will help further exploitation of these resources as live bait and for commercial purposes. From the structure of these fishes it is inferred that like all deep bodied and compressed forms they are slow swimmers and that they can with ease maintain a free position in the water, without the necessity of a support, remaining as if suspended at a certain distance from the surface. The great developments of the luminous organs, combined with the large eyes (Sternoptychidae) indicate the nocturnal habits of the fish, which would enable it to descend to a greater depth during daytime. (Gunther 1873-1876).

Photophores are one of the very important characteristic features of these fishes. Small photophores of other mesopelagic fishes are thought to provide protective adaptation to the luminous field created by the isotropic radiation of spontaneous bioluminescence. The species with numerous small photophores like *Icthyococcus* species and *Vinciguerria* species invariably have a dark body colour and tend to migrate to the lower mesopelagic zone during daytime. Multiple small photophores have independently converged in various groups of fish and provide camouflage by blurring the silhouette for dark colored fishes inhabiting the lower mesopelagic zone where variable bioluminescence is a major component of the total luminous field. In the bathypelagic zone only camouflage coloration provides cover, as bioluminescence is minimal.

Sampling the fishes of the mesopelagic zone in the dimly lit upper mid water of the open oceans between about 100 and 1000m is difficult. Most of the mesopelagic species are daily vertical migrators and there is evidence that they are continually altering their depth, although most of the change comes at dusk and dawn. Furthermore, the physical factors that appear to control the depth at which these fishes lie (transparency, temperature and the like) vary horizontally over the distance of a few miles. The arrangement of fishes in a water column is continually changing from moment to moment and place to place. It is for this reason, as well as the sheer size of the area involved, that so little is known about the distribution of mesopelagic organisms in any ocean. (Backus *et al.*, 1970).

Developments in hydro acoustic instruments during the last forty years have revolutionized the techniques of fish detection, locating fishing grounds and fish resource estimation. Starting from simple echo sounders, the present day equipments help in qualitative and quantitative assessment with better resolution and precision. In India the era of application of acoustics in fisheries investigation began in the late fifties with the import of few vessels from Norway for fisheries Research and survey along the west coast of India. The instruments were used in general for quantitative studies of the fishery resources, plankton distribution, Deep scattering layer (DSL) and in a limited way for gross quantification of certain demersal fish resources.

The acoustic survey equipment system onboard **FORV *Sagar Samapda*** (Department of Ocean Development) (Figure1.1) used for DSL studies consists of scientific echo sounders EK 400 for detecting fish schools, DSL thickness and depth, Echo integrator for quantifying the biomass, Trawl sonde for lowering the net to the desired depth, Distance speed log to mark for every nautical mile while sailing and Data terminal T-703 for providing the integrator as a print out. The Isaacs Kidd Midwater Trawl (IKMT) is a gear onboard **FORV *Sagar Samapda***, used to collect the mesopelagic samples on observation of DSL recording in the echosounder.

The genus *Vinciguerria* of the order Stomiiformes belonging to the family Photichthyidae and fishes of the family Sternoptychidae were a important constituent of the DSL in the west coast of the Indian EEZ. Since not much is known about these fishes a detailed study was undertaken.

The objectives of the study are as follows:

1. To identify the fishes of the family Photichthyidae and Sternoptychidae up to species level and to study their occurrence, distribution, migration patterns, and seasonal, spatial, temporal, bathymetric and diurnal abundance along the west coast of India.

2. To study the biology of important species of the genus *Vinciguerria* such as:

    a. Reproductive biology i.e., maturation, spawning, ova diameter and fecundity.

    b. Food and feeding habits i.e., qualitative and quantitative analysis of gut contents, their food preferences and feeding intensity variation, spatially, temporally, seasonally, diurnally and in different length groups.

    c. To study the length-weight relationship of the species *Vinciguerria nimbaria* and *Vinciguerria lucetia*.

3. To identify potential areas and study the trophic relation of the families Photichthyidae and Sternoptychidae in the Indian EEZ.

1.1 Review of literature

Deep sound scattering layers in the ocean were first recognized in 1942 (Duvall and Christensen, 1946; Erying *et al.*, 1948; Raitt, 1948). They have since been found to be widespread in most of the major oceans except the Arctic and the Antarctic oceans. Johnson (1948) described diurnal vertical movements of various layers of DSL and linked them with plankton concentration. Robert (1962) reported that during the day the DSL's are at depths roughly between 700 and 2,400ft. At night they rise almost to surface and diffuse or may merge into a broadband extending down to 500ft. The true DSL's may be defined as the layers between 700 and 2,400ft, most of which rise to the surface at night. Kinzer (1969) reported strong DSL in the western Arabian Sea at 300-400m and sporadically another at 900-1100m during February to March. Silas (1972) made similar observations on the DSL of the Lakshadweep Sea. His observations pertain to the period at 17.00 hrs to 19.30 hrs. At the start two distinct bands one at the surface and other at 75-200m were present. Between 17.20 and 18.00 hrs discrete bands got seperated and descended from the second band and about 18.15hrs the second band slit and the lower layer migrated down by 19.30 hrs the latter descended to 350-450m. The intermediate layer remained at around 175-350m. The upper bioscattering layer close to the surface (which could have been formed mainly of phytoplankton) showed a slight decrease in intensity.

Baird (1971) studied the systamatics, distribution and zoogeography of the marine hatchet fishes (family Sternoptychidae). The Sternoptychidae are primitive stomiatoid fishes closely related to Gonostomatidae but differed from them morphologically due to their deep body shape. Harute and Kawaguchi (1976) reported three species of marine hatchet fishes *S. diaphana ,S. obscura and S. pseudoobscura* from the western North Pacific Ocean based on the materials collected by the **R/V *Tansei***; Ocean research,University of Tokyo. Borodulina (1977) described a new species *Stenoptyx psudodiaphana* from materials collected in the Southern parts of the Atlantic, Indian and Pacific oceans. Borodulina (1978) worked on the systematics, distribution and habitat of fishes of the oceanic genera *Argyropelecus* and *Sternoptyx* (Sternoptychidae). Badcock and Baird (1980) have remarked on the systematics, development and distribution of the hatchet fish genus *Sternoptyx*. Baguet *et al.*, (1980) reported on the luminescence of *Argyropelecus* photophores which were electrically stimulated.

Ahlstrom and Counts (1958) reported on the development and distribution of *V. lucetia* and related species in the Eastern Pacific. They have described the development from embryonic to adult stage. The distribtution of the larvae had been surveyed by cruises of the California Cooperative Oceanic Fisheries for two years i.e., 1951 and 1952. Silas and George (1969) observed the development and distribution of *V. nimbaria* off the west coast of India and the Lacccadive Sea. The species is found to occur more in the Open Ocean than in the neritic waters with high abundance during post and premonsoon months. Gorbunova (1981,1982) examined the distinctive characters of the four species of *Vinciguerria* i.e., *V. poweriae, V. attenuata, V. nimbaria* and *V. lucetia* and presented a key. He reports on the conditions of reproduction of the genus of *Vinciguerria*, samples of eggs, larvae and adults of *V. nimbaria* which indicate the high abundance of the species breeding in all the areas of the Indian Ocean north of 20° south except for shelf waters.

Johnson and Feltes (1984) described a new species of *Vinciguerria* from the red sea, and Gulf of Aquaba. They explained that *V. mabahiss* shares with its close congeners *V. nimbaria* (Jordan and Williams, 1896) and *V. lucetia* (Garman, 1899), in the presence of SO photophores but differs in having only 58-63 total body photophores and 37-38 vertebrae. Menon (1990) analysed the IKMT samples from DSL, collected during the **FORV *sagar Sampada*** cruises, for the biocomposition and reported the wide occurrence of *Vinciguerria* (25% of total fish biomass) with particular dominance in night hauls. Zelck (1993) studied the horizontal and vertical distribution of *Vinciguerria* layae at a water mass front in the Tropical NE Atlantic. Menon *et al.*, (1996) studied the distribution and abundance of the genus *Vinciguerria* in the DSL of the Indian EEZ with a note on the biology of *Vinciguerria nimbaria*. In the DSL fish biomass one of the dominant genus was *Vinciguerria* represented by three species,i.e, *V. nimbaria, V. attenuata, V. poweriae*. The occurrence of *Vinciguerria* was frequent in north west and south west areas of the Indian EEZ at varying depths. Invariably the species fed on copepods, ostracods, cladocerans, euphausids and fish larvae etc., with variations in feeding during day and night. The species spawns only once a year and the fecundity ranged from 140-170 ova in fishes of 34-55mm total length. Young *et al.*, (1996) worked on the distribution and community structure of mid water fishes in relation to the sub tropical convergence off eastern Tasmania, Australia. Four new records were identified from the study area. Myctophids and Stomiatoids were the main taxa captured.

Kawamura and Hamoaka (1982) worked on the feeding habit of *V. nimbaria* found from the stomach of Brydes whales in the southwestern North Pacific. Kalnina *et al.* (1984) reported on the size, weight, food composition, fecundity and nutrition of

V. nimbaria an abundant species in the mesopelagic zone of the Indian Ocean. Lipskaya (1985) found out that the fry of the panama light fish *V. lucetia* fed actively on zooplankton (copepod and *oncaea species* accounted for 90% and 50% respectively). The feeding rhythm was related to diurnal vertical migrations of copepods. Villavicencio *et al.*, 1989 recorded the mortality of *V. lucetia* in La Paz Bay in April 1985. They discussed the possible causes of this die off. Rees *et al.*, (1990) studied the feeding habits of the vertically migrating Gonostomatiod fish *Vinciguerria nimbaria* off Southern Japan in relation to its food organisms, process of digestion and dial vertical migration. Food organisms were composed mainly of small to moderate sized copepods, which live almost entirely in the 0-200m oceanic zones. *V. nimbaria* was found to feed twice a day. Sieg (1992), studied the histology of the nutritive condition of larval and metamorphosing fishes of the family Photichthyidae sampled in the Central Arabian Sea and in the continental shelf off Pakistan. The results of this stage specific analysis showed generally a decreasing frequency of poor nutritional condition with organic development.

Marchal and Lebourges (1996) reported that *V. nimbaria* instead of diving to a great depth during the day as usual remained in the upper layers and tuna was found to feed on them. They analyzed the stomach contents of *V. nimbaria* from an eastern area of the tropical Atlantic Ocean. Stomach contents consisted of zooplankton of which 90.7% were copepods (*Calanus*, *corycaeus* and *candaxia*), 1% amphipods, 3.8% ostracods and 4% non-identified organisms. They suggested that chlorophyll content measured in adult *V. nimbaria* stomachs comes from ingested copepods and the species is entirely zooplanktivore. They explained the need to use acoustics for successful sampling. Shevchencko (1996) described the feeding of the oceanic light fish *Vinciguerria nimbaria* in the dynamically active zones of the eastern equatorial Atlantic.

Since not much work has been done on this species in the Arabian Sea the present work is aimed at bringing out the importance of these fishes in the Indian EEZ, which would help in their further exploitation as a live food for commercially important fishes.

Chapter - II

Distribution

2. DISTRIBUTION OF FAMILY PHOTICHTHYIDAE AND STERNOPTYCHIDAE

2.1.Introduction

The Arabian Sea is one of the most productive oceanic areas in the World (Ryther *et al.*, 1966). It has wide and variable ranges of physical and chemical conditions for biological production in relatively small temporal and spatial scales. This is because it is located at the Northern border of the Western Indian Ocean and is thus subject to the monsoon seasons causing unique and highly variable circulation systems. (Duing, 1970;Wyrtki ,1973; Qasim, 1982; Shetye *et al* ., 1991).

The studies on the distribution of fishes belonging to the families Photichthyidae and family Sternoptychidae were available in few works such as in the Costa RicaDome region (Anguilar Ibarra *et al.,* 1994); Eastern Equatorial Atlantic (Roger *et al.*, 1994); South and East off Japan (Wang and Chunsheng, 1994). Zelck (1993), Ponomareva *et al*., (1978) and Mukhacheva (1978) studied the distribution of the genus *Vinciguerria* in the Tropical NE Atlantic , Australian New Zealand region and Indian Ocean . Menon (1990) and Silas and George (1969) worked on the biology and distribution in the Indian EEZ. Harold *et al*., (1990) and Krefft (1983) reported the distribution of *Icthyococcus ovatus* in the Atlantic Ocean and the Canadian Atlantic region. Robinson *et al.*, (1997) showed the distribution of *V. lucetia* in the Shelf off Baja California, Mexico. The distribution of *Vinciguerria nimbaria* has been discussed by Lebourges and Marchal (1997) (Atlantic Equatorial current region), Kalinina (1988) (Tropical East Atlantic) and Legand *et a.l.*, (1974) (Eastern Indian Ocean). Backus and Craddock (1982) and Loch (1980) studied the distribution of the family Sternoptychidae in the Gulf Stream cold core ring and the North pacific.

The vertical distribution patterns in the mesopelagic fishes have been reported in Arabian Sea (Ropke, 1993; Menon, 1990), Tropical East Atlantic (Kalnina, 1988), Gulf stream cold ring (Backus *et al.*, 1982), Australian New Zealand region

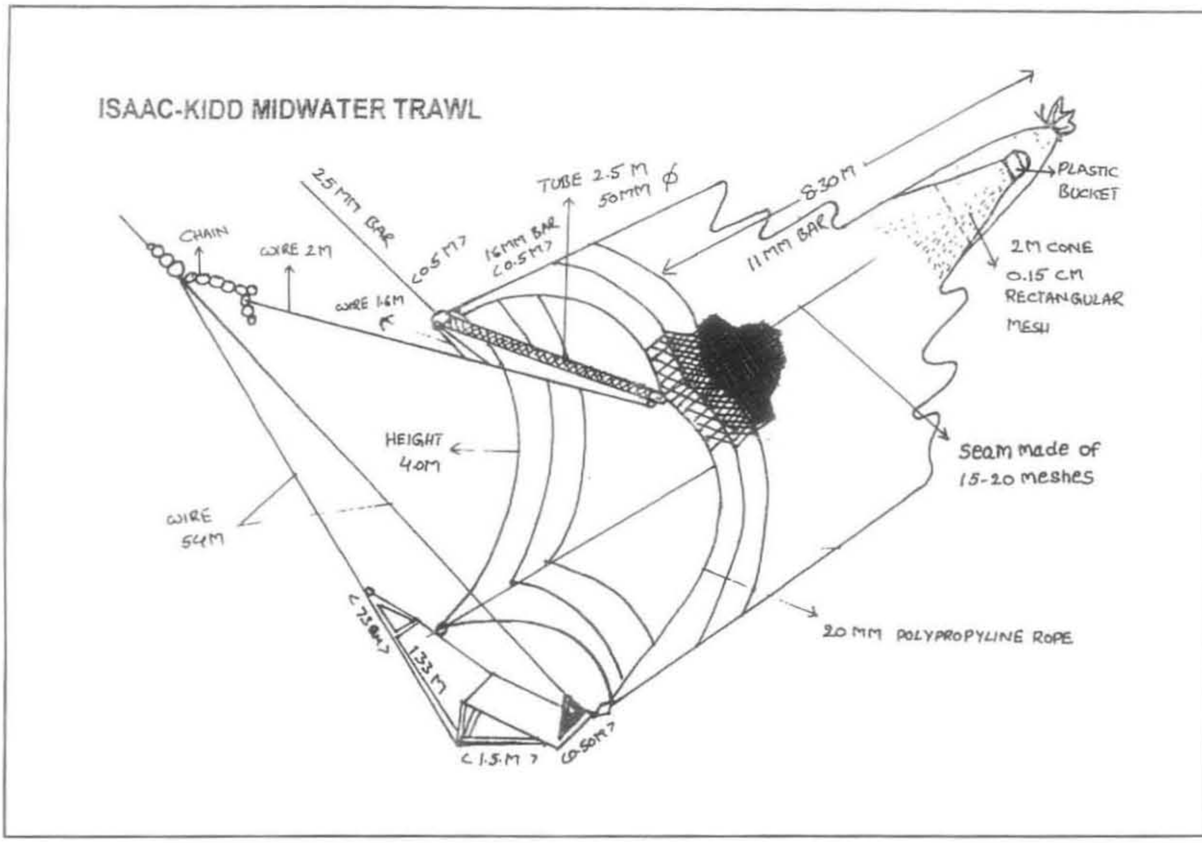


Figure 2.1: Rigging of the Isaacs - Kidd Midwater Trawl (1 KMT)

Depressor made of 5mm Aluminium, total length 2.5m,Weight 25Kg.

Source: N.G.Menon,2000.Marine Fisheries Research & Management ,p.650

Figure 2.1a : ISAAC - KIDD MIDWATER TRAWL IN ACTION

(Ponomareva, 1978) , Eastern Equatorial Pacific Ocean, (Gorbunova,1981) and Eastern Indian Ocean (Legand and Rivaton, 1969). Since not much is known on the distribution of the genus *Vinciguerria* and family Sternoptychidae in the Arabian Sea the present study was undertaken to elucidate further on these aspects.

2.2 Methodology:

Sampling: The Isaacs- Kidd Midwater trawl (IKMT) (Figure 2.1), the gear onboard **FORV *Sagar Sampada*** was specially designed for collecting DSL samples. This was made of nylon webbing with four sections of different mesh sizes of 25mm, 16mm, 11mm and 5mm and length of 500mm, 500mm, 8250mm and 1750mm respectively totaling 11m. The width was tapered from 2500mm at the mouth opening to 750 mm at the cod end. A depressor made of 5mm aluminium; total length 2.5m, weighing 25 kg is attached to the gear in order to maintain the proper opening of the net to maximum of 4 m. A 5 litre capacity bucket is attached to the cod end where the samples of DSL components get collected. The towing speed is 3 knots. The fishing warp is paid out at the rate of 25 meters per minute and retrieved at 12 ½ meters per minute. The vessel is sailed along the predetermined track having all the instruments preset for the required programme. The echo sounder was run continuously day and night to locate the DSL. Logmarker is set to mark every one nautical mile sailed. Latitude and longitude against time and date are recorded in the echogram for every two hours in order to refer back, to study their behaviour, migration, abundance and geographical distribution. The IKMT was operated, by observation of the DSL on the echogram, making an oblique haul lasting 30 minutes. The IKMT at work is as seen in Figure 2.1a. At dragging time the speed of a net is 5556m per hour. When echo mark of DSL is observed constantly and in significant layers, the IKMT is lowered (transducer fused on the head slope at the depth at which DSL appeared by observing trawl sonde recorder). The vessel speed and warp length of the net is maneuvered in such a way that the net followed the DSL and trapped them.

After hauling the net onboard the net was washed thoroughly in order to collect the samples in the bucket. The bucket was removed and washed again. The collected sample volume was taken by displacement volume method with the help of measuring cylinder. The total sample was preserved in 10% formalin and brought to the lab where the fishes of the families Photichthyidae and Sternoptychidae were identified and sorted out to the species level.

The occurrence (numbers per haul) and distribution for the species of both the families was studied spatially, seasonally, bathymetrically and temporally.

2.2.1 Biomass Estimation

Displacement volume method: A measuring cylinder is filled with water to a known level (initial reading) and the sample is added, after the displacement of the water level by the sample the reading is noted. The difference between the initial and final reading is the displaced volume of the sample.

The wet weight of the sample is taken as follows: the sample was washed thoroughly and then blotted with dry filter paper till the moisture is absorbed and it was transferred to the dry paper. The weight of the sample was taken in an electronic digital balance with an accuracy of 0.001mg. This was taken as the wet weight of the sample. After taking the numerical data volume and wet weight of each group, the data is estimated to $1000 m^3$.

The biomass is estimated using 'Swept Area' method. Sparre and Vanema (1992). The average biomass per unit area was estimated using the equation:

$$B = \frac{(C\,w/a)*A}{X_1}$$

Where,

Cw = Catch in weight of a haul,

a = the area swept by the gear during one unit of effort computed from the equation

$$a = t * v * h * x_2$$

Where ,

t = time equal for trawling (3 knots)

v = velocity of trawling (3 knots)

h = average head rope length of IKMT

x_2 = effective net opening which was taken as 0.5 as suggested by Pauly (1983).

A= total area swept and

X_1=portion of biomass actually retained by the gear (taken as 0.5 here).

The biomass in tonnes 1 ° sq was calculated by taking into consideration the DSL thickness (in meters), the average biomass (Gm/1000m^3) of the collection taken from that area and these have been extrapolated to compute the biomass 1° square (Gulland, 1975).

2.3. Results

The families Photicthyidae and Sternoptychidae contributed to 29.31% of the nektonic biomass of the DSL. The area covered was from 6°02'-21°00'N and 66°00'-77°00'E of a total of 12 cruises. Of the the two families studied family Photichthyidae contributed 97.2 % and Sternoptychidae were 2.7% respectively.

2.3.1 Family Photichthyidae

In the present study 3 species of family Photichthyidae i.e., 2 species in the genus *Vinciguerria* (*V. nimbaria, V. lucetia*) and one genus *Icthyococcus* with species *I.ovatus* was encountered in the Eastern part of the Arabian Sea. The distribution of these fishes and occurrence was studied based on its numerical abundance and biomass estimated in tonnes (1°square) in the IKMT collection.

2.3.2 General Distribution

The family Photichthyidae was recorded from 116 stations (46 Day and 70 Night). The highest catch of 1144 numbers were recorded from the depth of 616m at Lat.15°47'N and Long.72°40'E The next highest catch of 459 numbers were reported

Table 2.1: Day and Night combined data of family Photichthyidae of occurrence of more than 20 numbers

Sl.No.	Month	Stn.depth (m)	Opn.depth (m)	Lat	Long.	No
1	April	616	75	15°47'	72°40'	1144
2	April	4525	260	9°59'	70°01'	459
3	November	3391	45	17°29'	66°2[illegible]'	397
4	March	2412	65	17°00'	70°59'	372
5	July	1835	50	12°30'	73°30'	277
6	December	2440	40	20°55'	66°55'	225
7	March	1018	75	20°59'	68°58'	213
8	May	1926	80-90	10°29'	73°30'	198
9	September	2749	40	8°00'	75°00'	196
10	November	3451	3451	16°27'	70°27'	186
11	April	1199	150-200	17°00'	71°46'	183
12	April	792	300	12°34	74°06'	168
13	March	2382	35	21°00'	66°59'	156
14	December	1937	340	13°01	72°57'	156
15	November	2992	75	20°30'	68°21'	152
16	October	431	300	12°29'	74°09'	149
17	October	3870	60	16°25'	67°30'	136
18	October	4103	400	13°28'	67°30'	125
19	October	3359	60	17°23'	69°30'	125
20	October	3394	60	17°30'	67°24'	119
21	November	764	35-45	18°35'	70°17'	114
22	March	3539	190	16°59'	68°00'	103
23	December	1632	50	12°56'	71°52'	96
24	July	1584	60-70	12°30'	71°29'	94
25	November	3108	80	19°29'	67°29'	93
26	March	2766	310	20°58'	67°57'	91
27	November	3179	130-135	19°29'	68°30'	89
28	May	2770	40-50	8°00'	74°04'	80
29	May	2171	30-40	6°36'	76°26'	80
30	November	108	50	21°26'	68°30'	78
31	May	1020	60	12°58'	72°04'	67
32	September	1980	350	10°00'	73°00'	66
33	October	4452	120	10°31'	68°32'	65
34	November	1182	35	19°33'	69°20'	64
35	November	847	40	20°35'	69°14'	64
36	December	2405	320	13800'	70°57'	63
37	December	2000	100	8°34'	72°29'	62
38	December	2618	40	15°00'	70°59'	55
39	December	1778	100	10°29'	73°26'	46
40	October	3991	750	14°31'	67°32'	45
41	December	3582	40	16°56'	68°54'	45
42	March	2809	320	16°59'	68°00'	44
43	May	4181	90	8°00'	70°02'	40
44	December	3485	340-400	16°58'	69°59'	39
45	November	1099	30	15°31'	71°38'	38
46	November	3399	225	15°28'	70°26'	37
47	July	3440	60	10°30'	70°26'	34
48	May	4189	250	12°59'	69°02'	33
49	April	395	180	12°28'	74°09'	32
50	December	200	40	15°00'	73°00'	32
51	December	1188	40	20°56'	69°00'	32
52	May	2415	390-400	6°38'	77°31'	28
53	September	3646	280	10°00'	71°00'	25
54	December	2665	280-300	21°00'	67°58'	24
55	March	227	185	16°59'	71°51'	22
56	April	242	205	16°30'	72°14'	22
57	December	3476	340	14°59'	70°01'	21
58	May	1864	50	8°30'	73°32'	21

Table 2.2: Occurrence of family Photichthyidae at night more than 20 numbers

Sl.No.	Month	Stn.depth (m)	Opn.depth (m)	Lat.	Long.	No
1	September	616	75	15°47'	72°40'	1144
2	November	3391	45	17°29'	6[illegible]°21'	397
3	March	2412	65	17°00'	70°59'	372
4	July	1835	50	12°30'	73°30'	277
5	December	2440	40	20°55'	66°55'	225
6	March	1018	75	20°59'	68°58'	213
7	May	1926	80-90	10°29'	73°30'	198
8	September	2749	40	8°00'	75°00'	196
9	November	3451	3451	16°27'	70°27'	186
10	March	2382	35	21°00'	66°59'	156
11	November	2992	75	20°30'	68°21'	152
12	October	3870	60	16°25'	67°30'	136
13	October	4103	400	13°28'	67°30'	125
14	October	3359	60	17°23'	69°30'	125
15	October	3394	60	17°30'	67°24'	119
16	November	764	35-45	18°35'	70°17'	114
17	March	3539	190	16°59'	68°00'	103
18	December	1632	50	12°56'	71°52'	96
19	July	1584	60-70	12°30'	71°29'	94
20	November	3108	80	19°29'	67°29'	93
21	March	2766	310	20°58'	67°57'	91
22	May	2770	40-50	8°00'	74°04'	80
23	May	2171	30-40	6°36'	76°26'	80
24	May	1020	60	12°58'	72°04'	67
25	October	4452	120	10°31'	68°32'	65
26	November	1182	35	19°33'	69°20'	64
27	November	847	40	20°35'	69°14'	64
28	December	2000	100	8°34'	72°29'	62
29	December	2618	40	15°00'	70°59'	55
30	December	1778	100	10°29'	73°26'	46
31	December	3582	40	16°56'	68°54'	45
32	May	4181	90	8°00'	70°02'	40
33	November	1099	30	15°31'	71°38'	38
34	October	3440	60	10°30'	70°26'	34
35	April	395	180	12°28'	74°09'	32
36	December	200	40	15°00'	73°00'	32
37	December	1188	40	20°56'	69°00'	32
38	September	2415	390-400	6°38'	77°31'	28

from the station depth of 4525m at Lat. 9°59'N and Long.70°01'E. Two other stations recorded the catch of 397 and 372 numbers in the station depth of 3391m and 2412m respectively. At 22 stations the number of specimens caught exceeded 100 numbers. The details of station depth, position, and depth of operation, of those caught above 20 numbers are as presented in Table 2.1. From the above observations it is clear that the abundance was more in the area of Lat. 15° 00'N and above. The map showing the distribution of family Photichthyidae in the west coast is shown in Figure 2.2.

2.3.1.1 Diurnal distribution

Out of 70 night IKMT stations 39 stations yielded catch of 50 numbers and more. Another 10 stations reported catches varying from 10-50 numbers. The maximum catch of 1144 numbers was recorded at the Lat. 15°47'N and Long. 72° 40'E at a depth of 616m. The next higher numbers of 397and 372 were recorded in 2 other stations. The details of station depth, location, depth of operation, and catch (20 numbers and above) are given in Table 2.2. Figure 2.2 a shows the distribution of the family Photichthyidaae during night.

Day hauls of 46 IKMT stations showed that the catches was much lower when compared with that of the night catches. A catch more than 10 numbers were recorded in 27 stations. Highest catch of 459 numbers was recorded from the Lat. 9°59'N and Long.70°01'E at the station depth of 4525m. More than 100 numbers were recorded from 24 stations. The detail of catch of more than 20 numbers, station position, depth of operation and station depth is as shown in Table 2.3 The map showing the distribution during day is seen in Figure 2.2 b.

2.3.1.2 Spatial distribution

The family Photichthyidae were more abundant in the higher latitudes of 15°-20°N. The highest mean catch per haul of 177 numbers were reported from 17°N followed by a catch of 133 numbers recorded from Lat. 15° 00'N. Table 2.4.

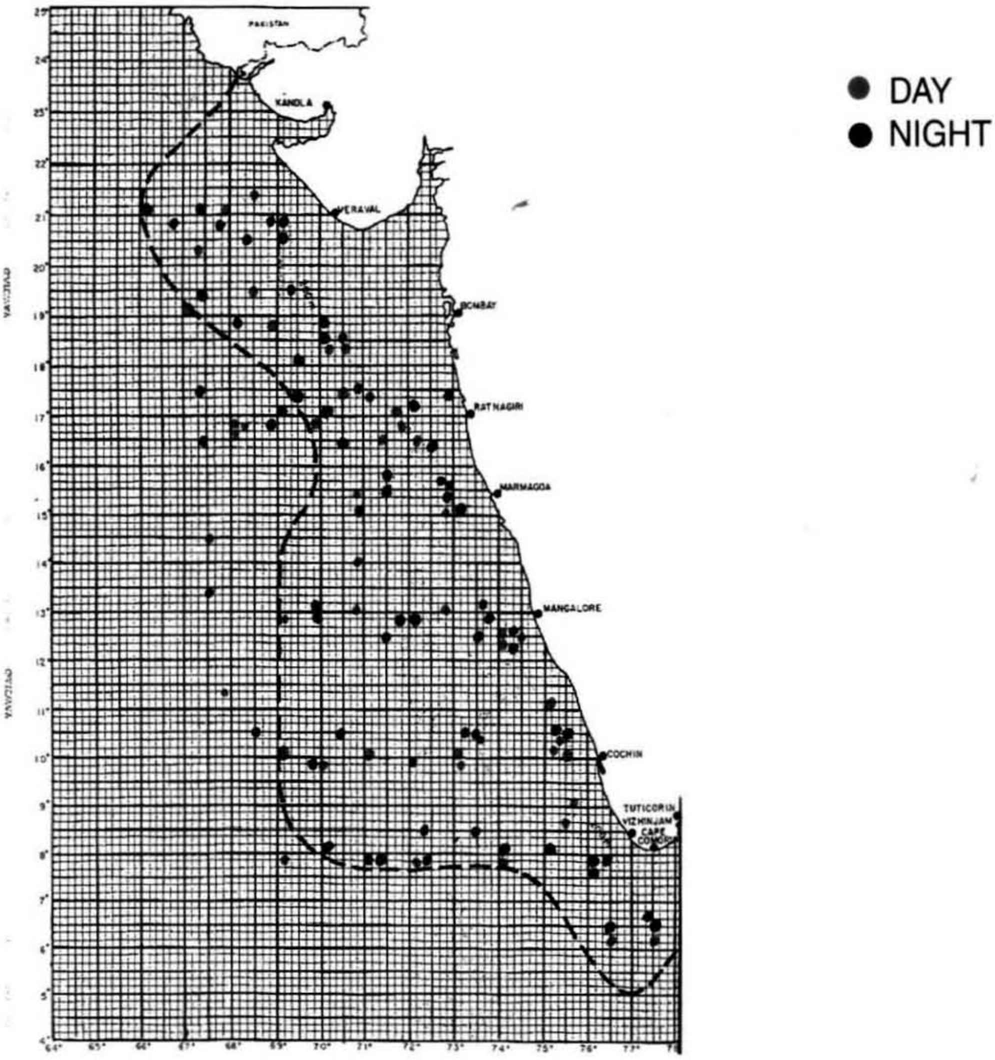


Figure 2.2 Day & Night occurrence of family Photichthyidae in the west coast

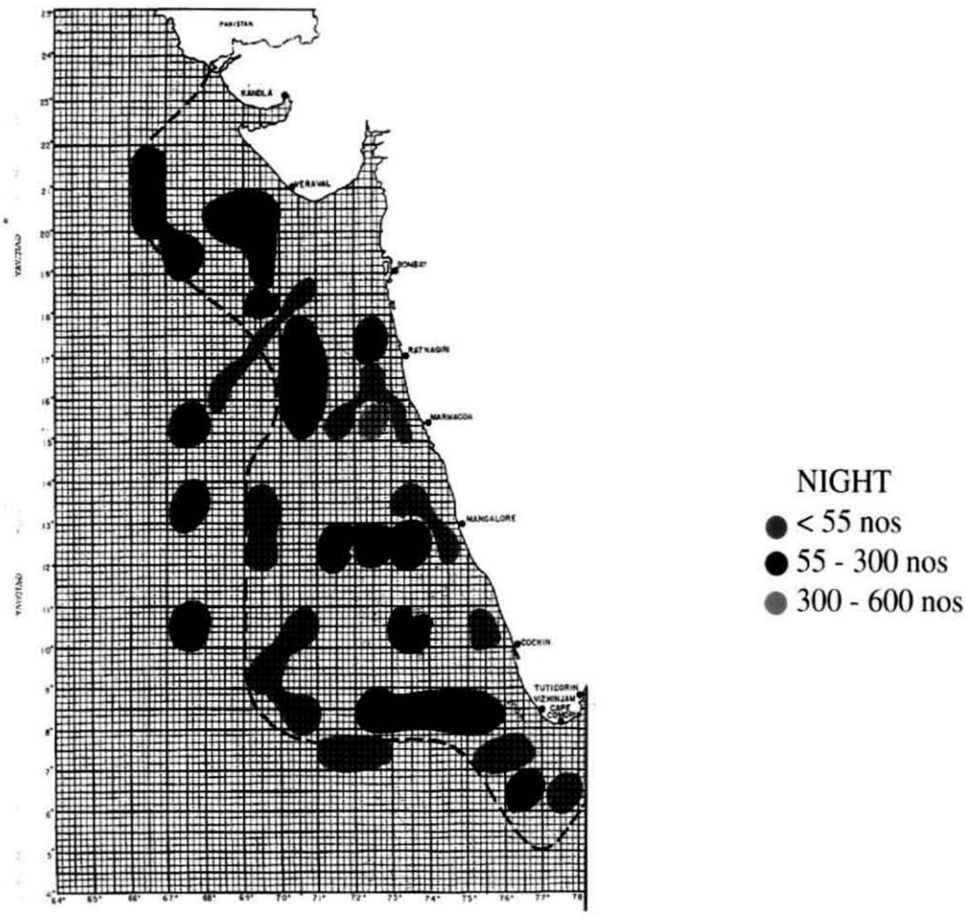


Figure 2.2a. Distribution of family Photichthyidae in the west coast during night.

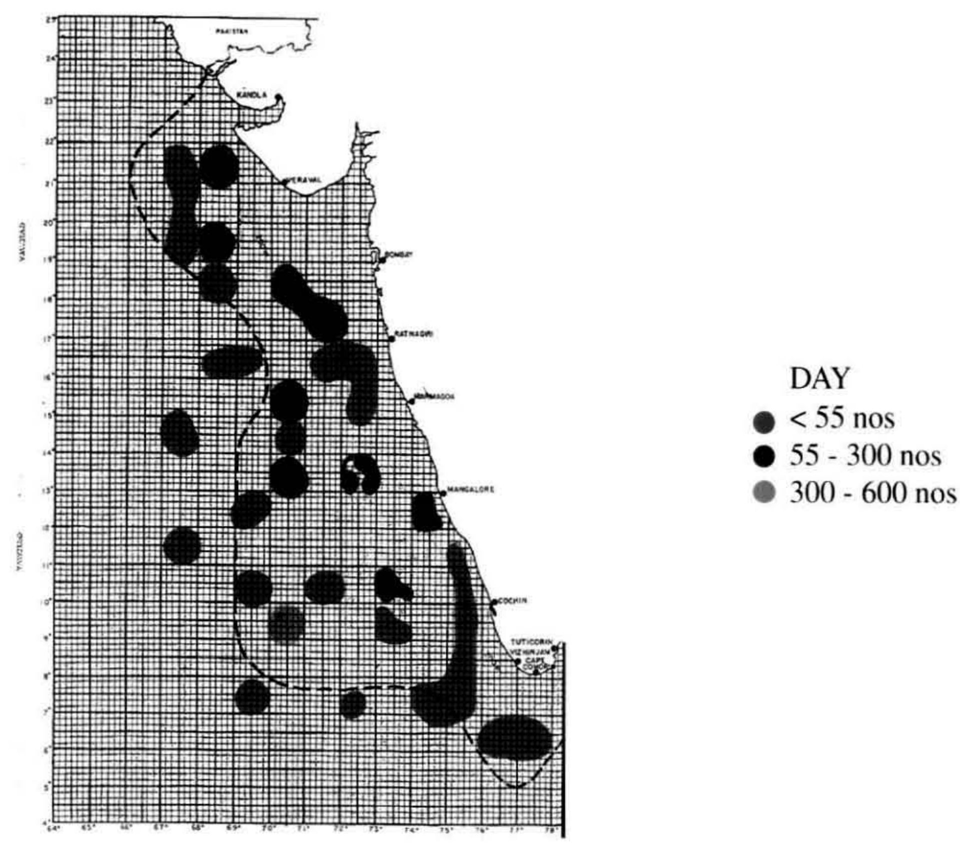


Figure 2.2b Distribution of family Photichthyidae in the west coast during day.

Table 2.3: Occurrence of family Photichthyidae during day more than 20 numbers

Sl.No.	Month	Stn.depth (m)	Opn.depth (m)	Lat	Long.	No
1	September	4525	260	9°59'	70°01'	459
2	April	1199	150-200	17°00'	71°46'	183
3	April	792	300	12°34	74°06'	168
4	December	1937	340	13°01	72°57'	156
5	April	431	300	12°29'	74°09'	149
6	November	3179	130-135	19°29'	68°30'	89
7	November	108	50	21°26'	68°30'	78
8	September	1980	350	10°00'	73°00'	66
9	December	2405	320	13°00'	70°57'	63
10	October	3991	750	14°31'	67°32'	45
11	March	2809	320	16°59'	68°00'	44
12	December	3485	340-400	16°58'	69°59'	39
13	November	3399	225	15°28'	70°26'	37
14	May	4189	250	12°59'	69°02'	33
15	September	3646	280	10°00'	71°00'	25
16	December	2665	280-300	21°00'	67°58'	24
17	May	227	185	16°59'	71°51'	22
18	April	242	205	16°30'	72°14'	22
19	December	3476	340	14°59'	70°01'	21

Night catch of 227 number/haul was from Lat.15°N. The next highest catch was recorded from Lat. 17°-18°N. The Night catch varied from 6 to 227 number/haul.

Day catches showed a variation from 2 to 156 number/haul. The highest catch recorded was from Lat. 9°N. The Latitudes 13°N and 17°N also showed good catches.

2.3.1.3 Seasonal distribution

The seasonal distributions of family Photichthyidae showed that they were available throughout the year in considerable quantities. The catch recorded varied between 39 and 128 numbers/haul. During Premonsoon the number recorded were 245, in monsoon it was at 204 and in post monsoon 218 number /haul. Thus the catch did not show much seasonal variation.

The diurnal distribution of the species showed variations. The night catches showed a higher value than the day catch. The night catches during premonsoon season was 378 number/haul. The monsoon and postmonsoon seasons recorded 322 number/haul. During day the catches were around 112 and 113 for premonsoon and postmonsoon months respectively. The monsoon season showed a low of 85 numbers /haul. (Figure 2.3)

2.3.1.4 Bathymetric distribution

To study the bathymetric distribution of these fishes the depth (vertical depths) was divided to four categoris i.e., 0-50m , 50-100m , 100-300m and depths greater than 300m. The depths horizontally were divided into 3 categories 100-300, 300-1000 and 1000-3000m.

The depth wise distribution (vertical) (Figure 2.4) showed that during day 109 number/haul was recorded from 100-300m depth. 63 number/haul was from 50-100m depth, 32 numbers were from depths higher than 300m and 22 numbers were from 0-

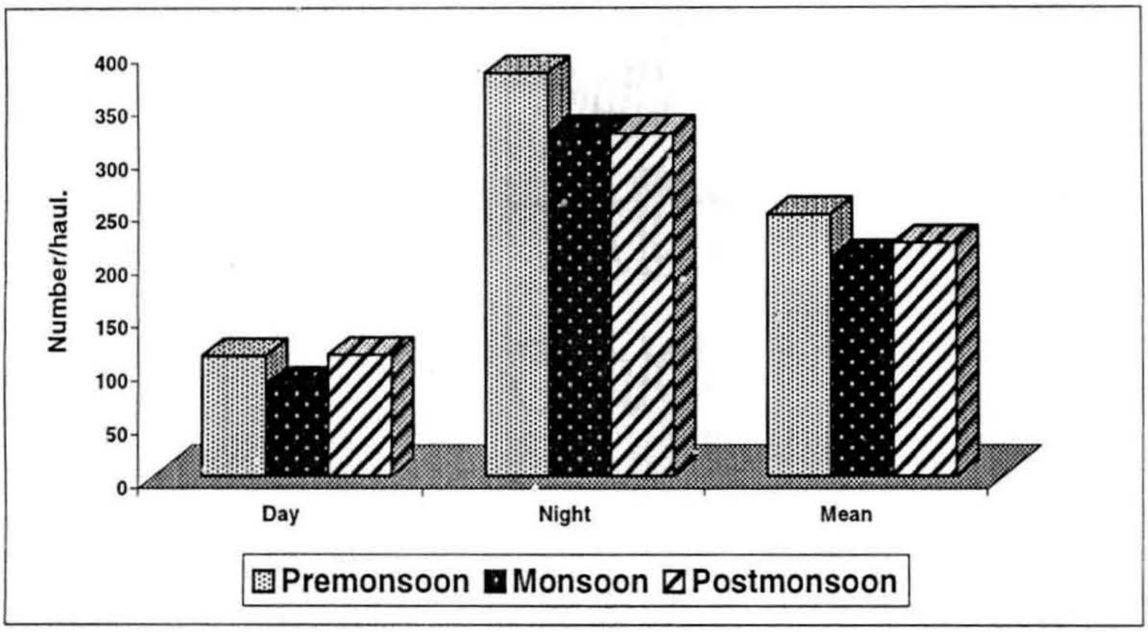


Figure 2.3 Seasonal Number/haul of family Photichthyidae

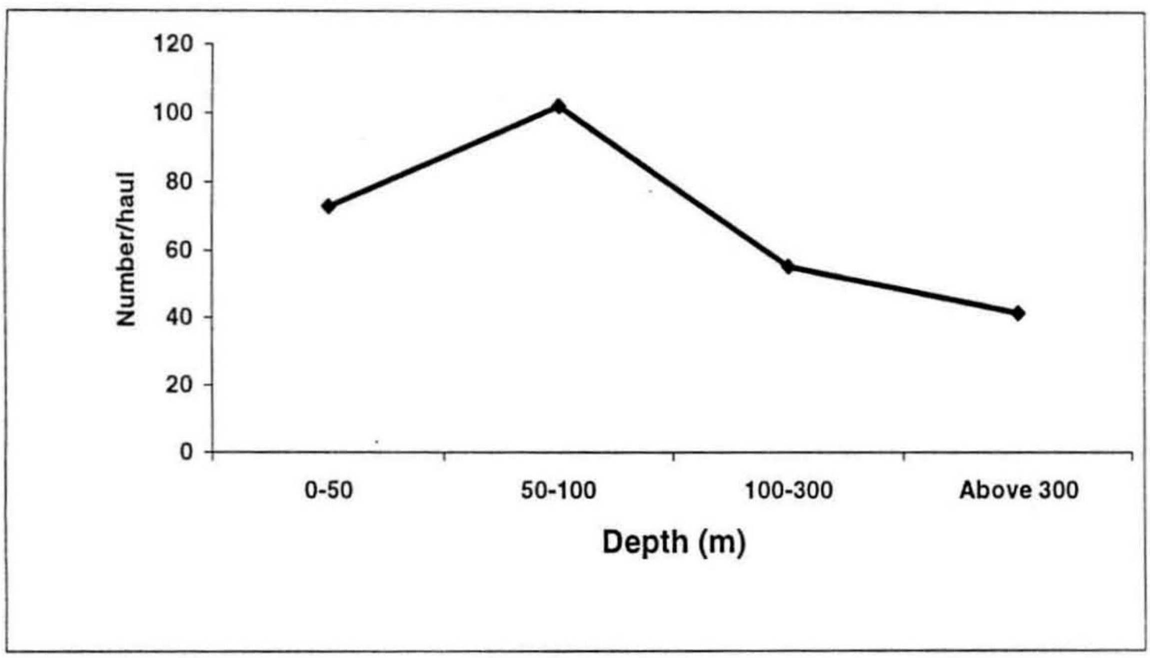


Figure 2.4 Depth wise distribution of family Photichthyidae pooled for night and day

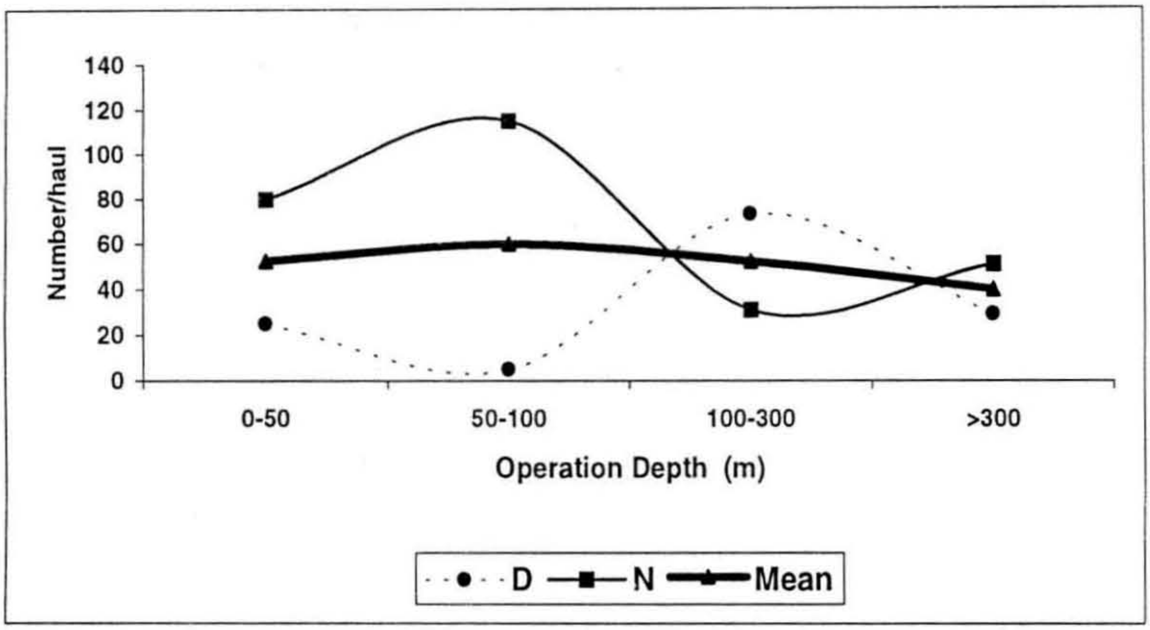


Figure 2.4a. Depth wise distribution of family Photichthyidae

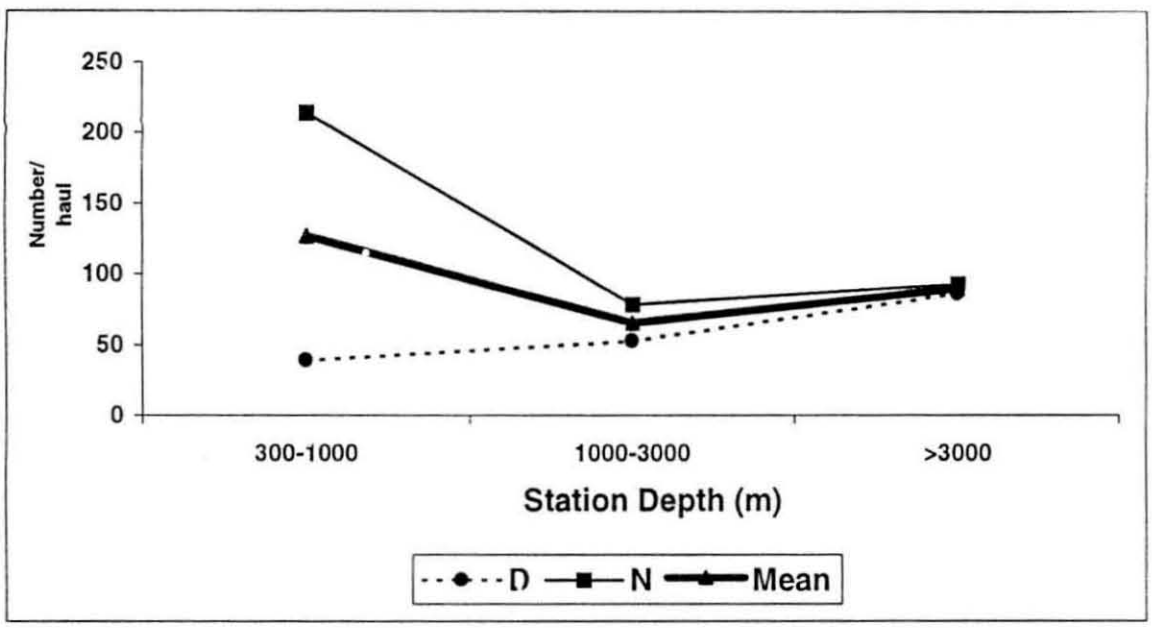


Figure 2.4b. Horizontal distribution of family Photichthyidae

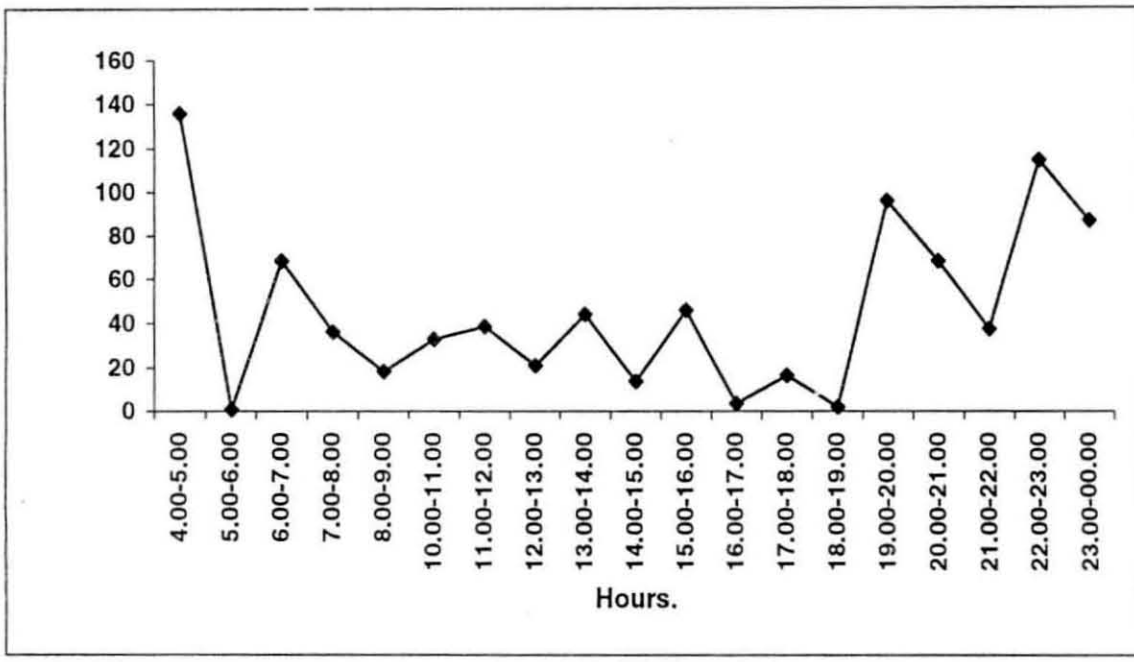


Figure 2.5 Temporal distribution pooled for family Photichthyidae

50m depth. During night hauls a higher number were seen from surface to 100m (240 numbers) and only 93 numbers from 100m to depth greater than 300m. Thus these observations show the diurnal migration of the fishes of the family Photicthyidae. (Figure 2.4a)

Variation in number/haul at different station depths i.e.,300-1000m,1000-3000m and depths greater than 3000m were found to be minimal during day. During night catches a higher number of 214 per haul were recorded at 300-1000m. At depths greater than 3000m, 94 number/haul was seen and 1000-3000m 79 numbers per haul were seen. (Figure 2.4b).

2.3.1.5 Temporal Distribution

The temporal distribution of the family Photichthyidae showed that thier ascent took place in the late evenings and ascended to the the surface in the late night. The fishes started their descent to the lower layers in the early morning hours. (Figure 2.5)

2.3.2 *Vinciguerria nimbaria*

2.3.2.1 General Distribution

Generally *V. nimbaria* was abundant in the Indian EEZ. (Figure 2.6) The IKMT catch (1976 numbers), of a total of 95 stations ranged from 1-1144 number / haul. The highest catch of 1144 numbers was recorded at station depth 616m ,operation depth, 75m, Lat.15°47'N and Long.72°42'E. A total of 9 hauls brought the catch more than 100 numbers. In 18 stations catch between 20-100 numbers was recorded. The details of the station of more than 20 numbers is as shown in the Table 2.5.

Table 2.5: *V. nimbaria* more than 20 numbers (Pooled)

Sl.No.	Month	Stn.depth (m)	Lat	Long.	Opn.depth (m)	Time	No
1	April	616	15°47'	72°40'	75	19.45-20.15	1144
2	November	3391	17°29'	60°21'	45	20.25-20.55	248
3	April	1199	17°00'	71°46'	150-200	17.20-17.50	183
4	May	1926	10°29'	73°30'	80-90	20.40-21.10	182
5	April	792	12°34	74°06'	300	7.10-7.40	168
6	November	3451	16°27'	70°27'	3451	20.00-20.30	156
7	April	431	12°29'	74°09'	300	7.10-7.40	149
8	July	1835	12°30'	73°30'	50	21.20-21.50	124
9	November	764	18°35'	70°17'	35-45	22.30-23.00	114
10	May	2770	8°00'	74°04'	40-50	21.45-22.15	80
11	September	4525	9°59'	70°01'	260	17.30-18.00	67
12	October	3394	17°30'	67°24'	60	5.00-5.30	66
13	October	3870	16°25'	67°30'	60	16.00-16.30	64
14	October	4103	13°28'	67°30'	400	20.00-20.30	61
15	December	1937	13°01	72°57'	340	13.45-14.15	61
16	July	1584	12°30'	71°29'	60-70	5.25-5.55	56
17	May	1020	12°58'	72°04'	60	20.15-20.45	55
18	November	2992	20°30'	68°21'	75	21.15-21.45	54
19	November	3108	19°29'	67°29'	80	21.00-21.30	42
20	May	1333.5	17°22'	71°10'	280	15.45-16.15	38
21	April	395	12°23'	74°09'	180	19.00-19.30	32
22	October	3991	14°31'	67°32'	750	13.30-14.00	31
23	November	1182	19°33'	69°20'	35	23.35-00.05	25
24	December	2440	20°55'	66°55'	40	20.30-21.00	25
25	April	242	16°30'	72°14'	205	7.05-7.35	22
26	October	3440	10°30'	70°26'	60	21.50-22.20	20
27	December	1778	10°29'	73°26'	100	23.10-23.40	20

Table 2.6 : *V. nimbaria* more than 10 numbers during night

Sl.No.	Month	Stn.Depth (m)	Lat	Long.	Opn.depth (m)	Time	No
1	April	616	15°47'	72°40'	75	19.45-20.15	1144
2	November	3391	17°29'	60°21'	45	20.25-20.55	248
3	May	1926	10°29'	73°30'	80-90	20.40-21.10	182
4	November	3451	16°27'	70°27'	3451	20.00-20.30	156
5	July	1835	12°30'	73°30'	50	21.20-21.50	124
6	November	764	18°35'	70°17'	35-45	22.30-23.00	114
7	May	2770	8°00'	74°04'	40-50	21.45-22.15	80
8	October	3394	17°30'	67°24'	60	5.00-5.30	66
9	October	4103	13°28'	67°30'	400	20.00-20.30	61
10	July	1584	12°30'	71°29'	60-70	5.25-5.55	56
11	May	1020	12°58'	72°04'	60	20.15-20.45	55
12	November	2992	20°30'	68°21'	75	21.15-21.45	54
13	November	3108	19°29'	67°29'	80	21.00-21.30	42
14	April	395	12°28'	74°09'	180	19.00-19.30	32
15	December	2440	20°55'	66°55'	40	20.30-21.00	25
16	November	1182	19°33'	69°20'	35	23.35-00.05	25
17	October	3440	10°30'	70°26'	60	21.50-22.20	20
18	December	1778	10°29'	73°26'	100	23.10-23.40	20
19	May	4181	8°00'	70°02'	90	20.00-20.30	19
20	May	1864	8°30'	73°32'	50	20.50-21.20	19
21	October	4452	10°31'	68°32'	120	5.00-50.30	19
22	October	3359	17°23'	69°30'	60	5.00-5.30	18
23	November	1099	15°31'	71°38'	30	19.00-19.30	17
24	December	1632	12°56'	71°52'	50	23.50-00.20	16
25	April	657	18°00'	70°43'	75	5.05-5.35	15
26	December	2000	8°34'	72°29'	100	20.45-21.15	12
27	May	3351	7°52	71°12	60-80	19.20-19.50	10
28	September	2415	6°38'	77°31'	390-400	21.00-21.30	10
29	November	2651	17°30'	70°29'	260	21.15-21.45	10
30	December	2618	15°00'	70°59'	40	22.30-23.00	10
31	September	2749	8°00'	75°00'	40	23.30-00.00	10

Table 2.7 : *V. nimbaria* more than 10 numbers during day

Sl.No.	Month	Stn.depth (m)	Lat	Long.	Opn.depth (m)	Time	No
1	April	1199	17°00'	71°46'	150-200	17.20-17.50	183
2	April	792	12°34	74°06'	300	7.10-7.40	168
3	April	431	12°29'	74°09'	300	7.10-7.40	149
4	September	4525	9°59'	70°01'	260	17.30-18.00	67
5	October	3870	16°25'	67°30'	60	16.00-16.30	64
6	December	1937	13°01	72°57'	340	13.45-14.15	61
7	May	1333.5	17°22'	71°10'	280	15.45-16.15	38
8	October	3991	14°31'	67°32'	750	13.30-14.00	31
9	April	242	16°30'	72°14'	205	7.05-7.35	22
10	May	4189	12°59'	69°02'	250	6.30-7.00	17
11	November	1617	16°33	71°28'	25	8.05-8.35	14
12	September	1980	10°00'	73°00'	350	7.45-8.15	13
13	April	300	8°40'	75°36'	60	7.35-8.05	11

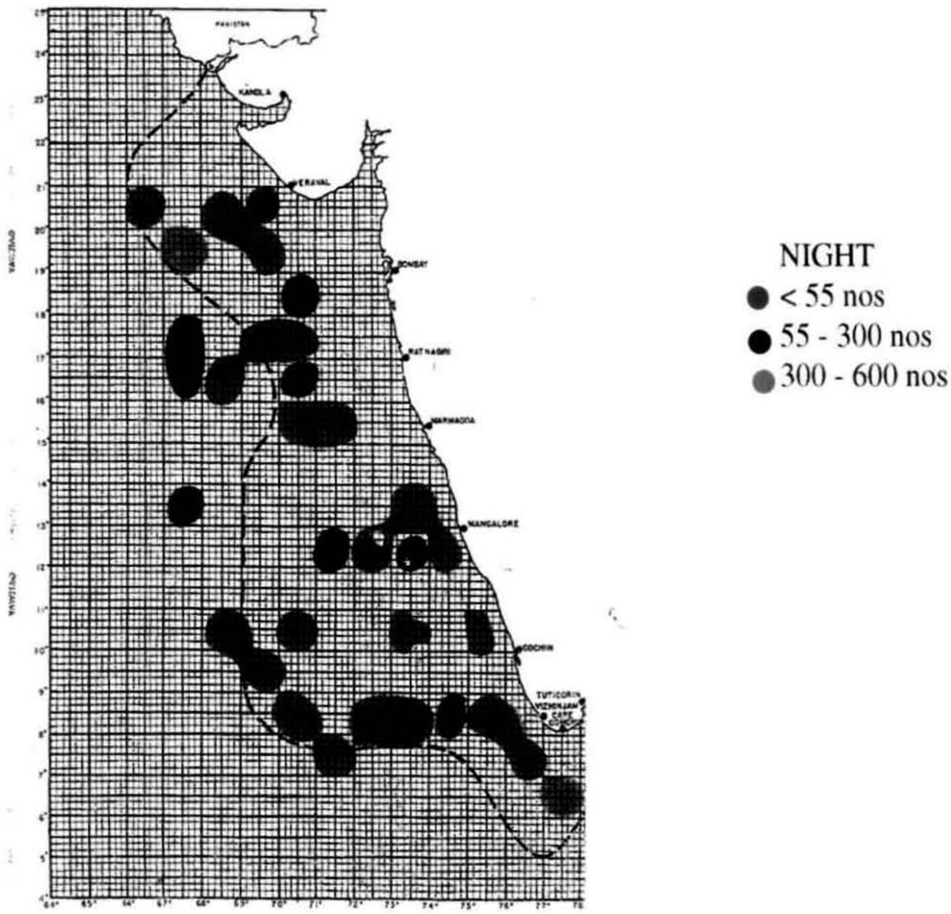


Figure 2.6a. Distribution of *V. nimbaria* in the west coast during Night

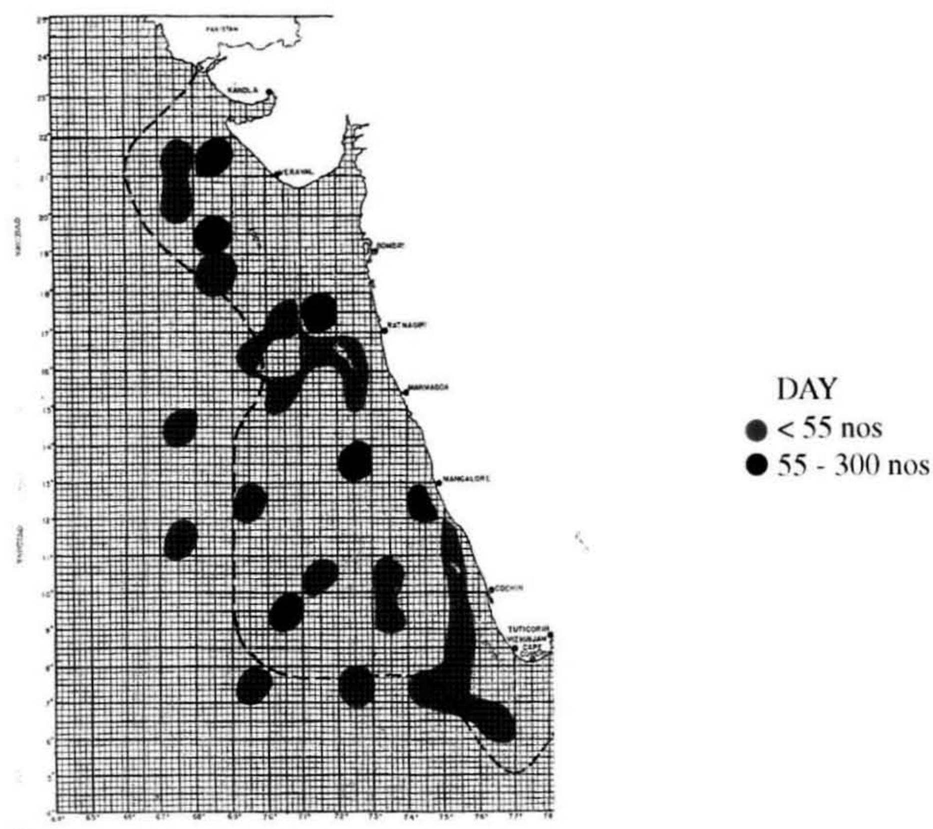


Figure 2.6b. Distribution of *V. nimbaria* in the west coast during day

2.3.2.2 Diurnal distribution

The IKMT caught *V. nimbaria* in 54 stations during night operations.The occurrence in numbers in the west coast during night is seen in Figure 2.6 a. The highest catch of 1144 number was caught during night. A total of 6 stations yielded the catch above 100 numbers. The catch of 20-100 numbers was from 12 stations. A total of 31 stations recorded catch of 10 numbers and above. The details of the catch above 10 numbers at night is as shown in the Table 2.6.

Day landings showed generally low values than night. The occurrence in numbers in the west coast during night is seen in Figure 2.6 b. Day catch maximum was at 183 numbers from 17°00'N Lat. and 71°40'E Long. Only 3 stations yielded more than 100 numbers. A catch of more than 20 numbers was recorded from 9 stations. The details of the catch of the staions which yielded more than 10 numbers are as shown in the Table.2.7.

2.3.2.3 Spatial distribution

V.nimbaria was present in all the latitudes (6°-20°) in the West coast of the Indian EEZ in considerable numbers with a abundance at Lat. 12°00'-18°00'N. The highest mean catch per haul of 149 numbers was recorded at Lat 15 °N. The Lat 17°N yield a mean catch of 80 numbers.

In the lower latitudes of 6°-11°N, *V. nimbaria* was poorly represented in the range of 1-21 numbers. Higher latitudes of 15°N –17°N recorded a catch of 149, 56 and 80 numbers respectively. The night hauls of IKMT brought the highest catch of 293 numbers /haul of *V. nimbaria* at 15° Latitude. High numbers of *V. nimbaria* was reported from Latitudes 15°N-18°N. The maximum catch during day at Lat.12°N was 84 number/haul. *V. nimbaria* was abundant at Lat.11° -17°N .(Figure 2.7).

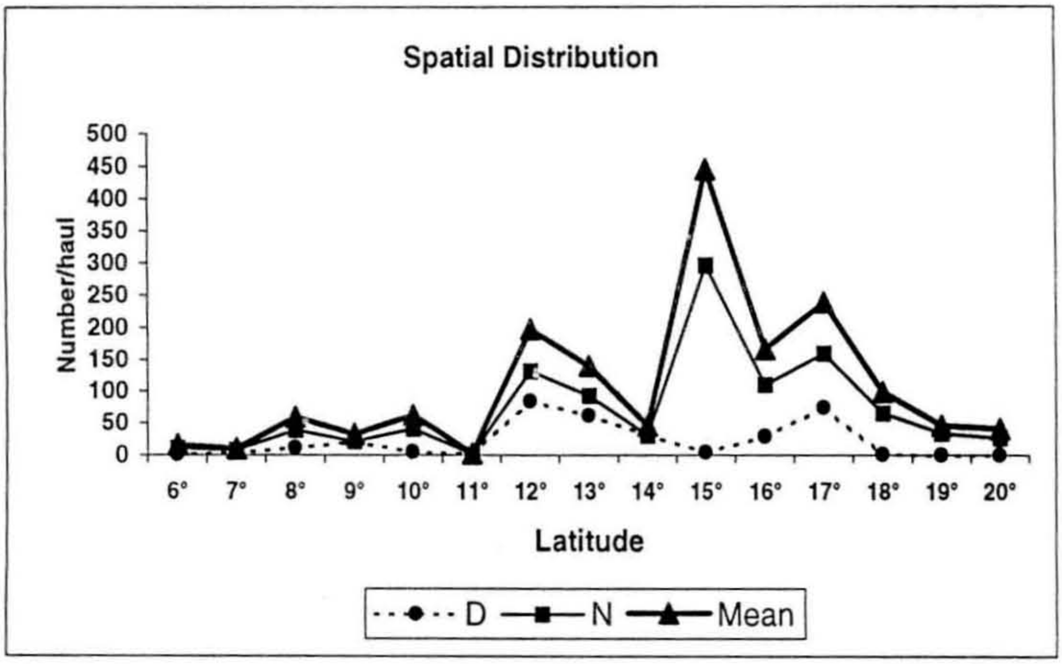


Figure. 2.7 Spatial Distribution of *V. nimbaria*

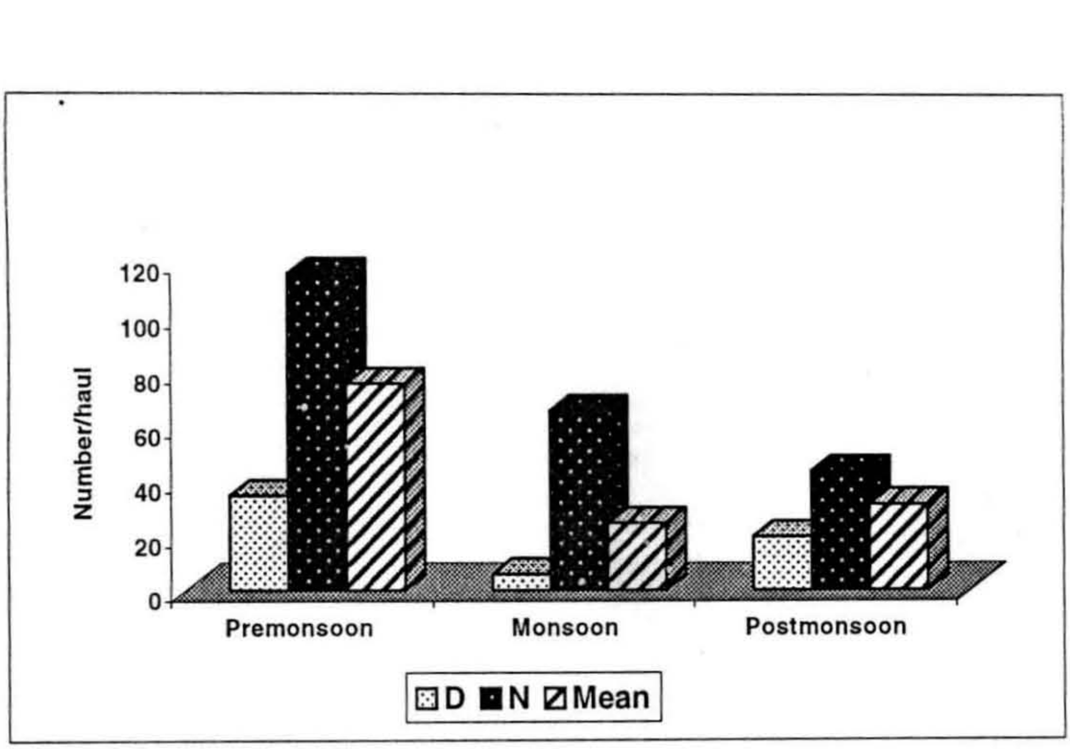


Figure 2.8 Seasonal distribution for *V. nimbaria*

2.3.2.4 Seasonal distribution

V. nimbaria was moderately abundant in all seasons. Premonsoon months have the maximum mean catch of 76 numbers followed by postmonsoon (32 numbers). Monsoon season yielded low of 25 numbers.

The night hauls showed a good abundance. The seasonal catch of 116 , 56 and 44 number/haul varied for premonsoon, monsoon and postmonsoon respectively. The day catches showed low values of 35, 20 and 6 number/haul for the three seasons. (Figure 2.8)

2.3.2.5 Bathymetric distribution

2.3.2.5a Vertical distribution

In the operational depth of IKMT *V. nimbaria* was available in the range of upto 300m. The mean catch showed the maximum abundance at 50 to500m depth. The catch ranged from 18 to 56 numbers.

The day catch showed a variation of 6-46 numbers with the maximum found in the depth of 100-300m. The night catch showed a fluctuation between 13 and 86 numbers. At depth range of 50-100m at night a maximum catch of 86 numbers was recorded. (Figure 2.9).

2.3.2.5b Horizontal depth

The species *V. nimbaria* occurred in station depth of 300 to 4633m. Its abundance was more in the depth range of 300-1000 m (92 numbers). During night it was found abundant in 300-1000m (146 numbers). The catch ranged between 32-146 numbers. During day the catch was between 20-38 numbers. (Figure 2.10).

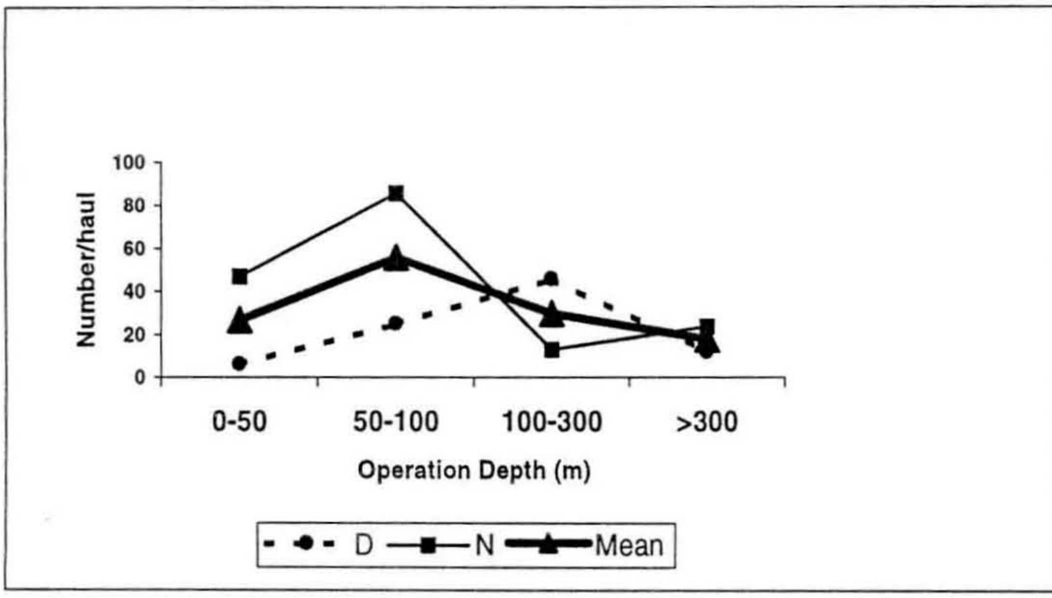


Figure 2.9 Vertical distribution for *V. nimbaria*

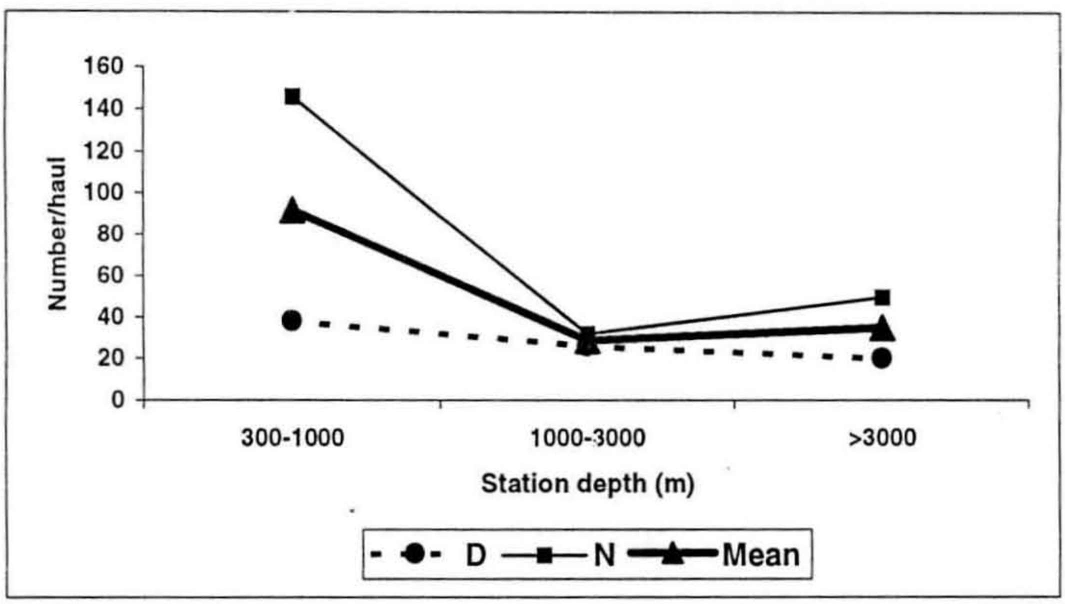


Figure 2.10 Horizontal distribution for *V. nimbaria*

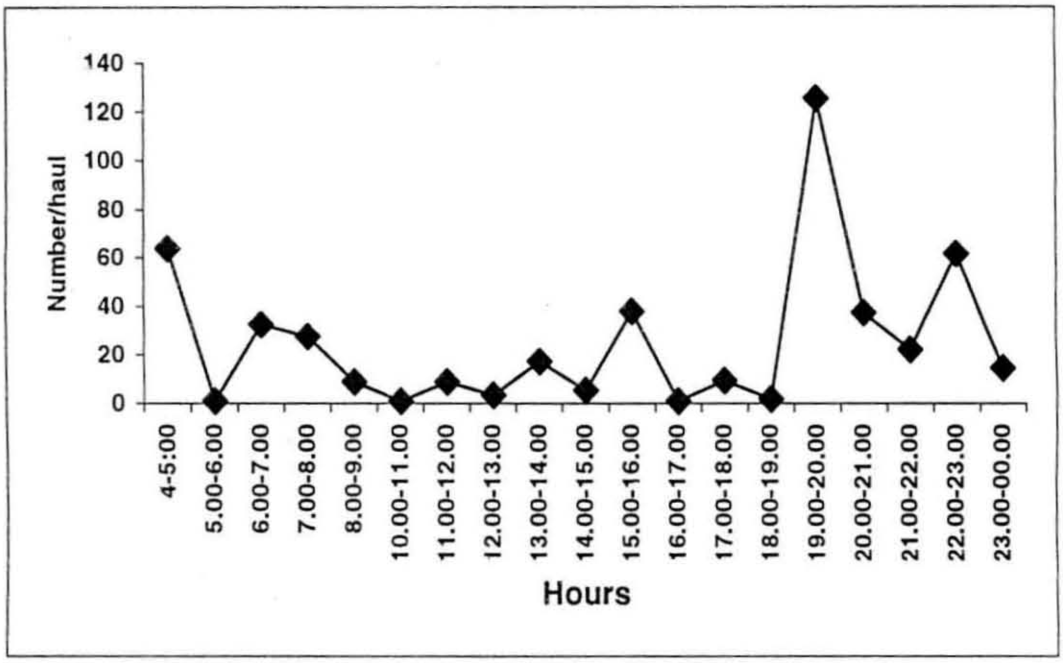


Figure 2.11 Temporal distribution for *V. nimbaria*

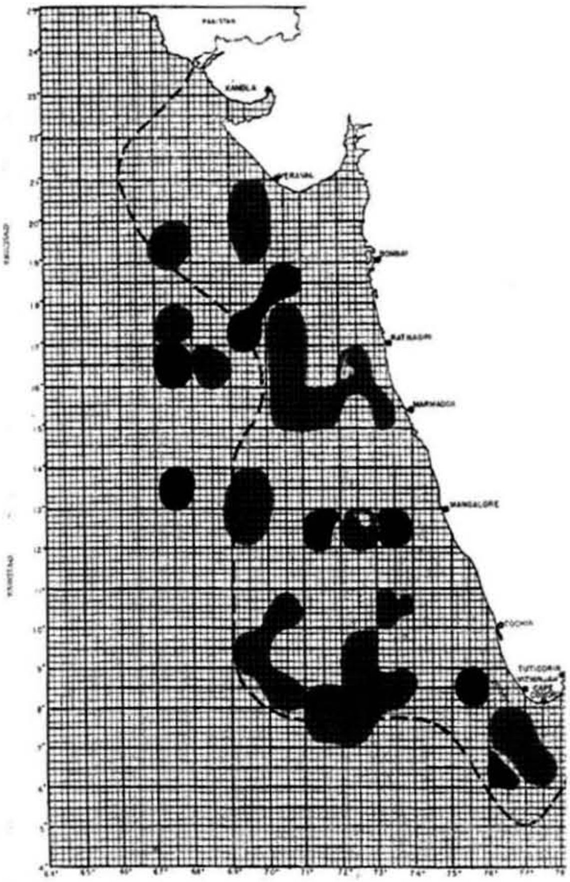


Figure 2.12a Distribution of ***V. lucetia*** in the west coast during Night

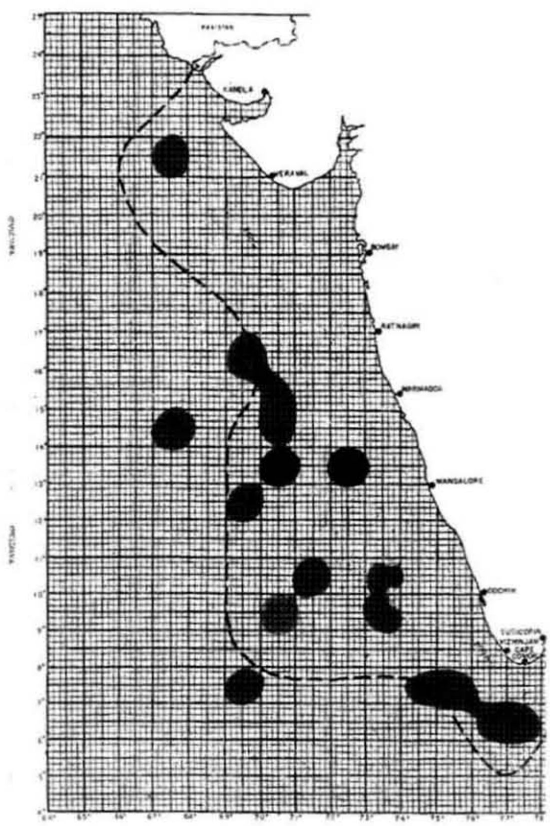


Figure 2.12b Distribution of ***V. lucetia*** in the west coast during day

2.3.2.6 Temporal distribution

Temporal distribution studies showed that in the west coast, *V. nimbaria* were seen at the surface from 4.00- 6.00 hrs, they were present at 0-100m (5.71%) and 100-300mm (6.73%) from 6.00-8.00hrs. were seen at 0-100m and 100-300m at 8.00-9.00hrs and below 300 from 10.00-15.00hrs. From 15.00-19.00 hrs were observed at 100-300m and below 300m. At 19.00 hrs the ascent was observed as a significant percentage was present at the surface layers from 0-300m. From 20.00-22.00 hrs they were seen at the surface layers and a small percentage were seen below 300m. From, 22.00 –00.00 hrs 100% of *V. nimbaria* were seen at the surface 0-100m. (Figure 2.11)

2.3.3 *Vinciguerria lucetia*

2.3.3.1 General distribution

The IKMT recorded *V. lucetia* in 64 stations in the west coast of India during the period of observation.

High numbers of *V. lucetia* was recorded in Lat.9°59'N and Long. 70°01'E in the operational depth of 260m. Only 7 stations yield more than 100 numbers. A total of 35 stations recorded a catch of more than 20 numbers. (Table 2.8).

The occurrence in numbers in the west coast for day and night is shown in the map .(Figure 2.12a and Figure 2.12b). In the Diurnal Catch two IKMT stations recorded a catch of 265 and 200 numbers of *V. lucetia* during night. Four stations recorded numbers between 100-200. The catch between 20 and 100 numbers was observed in 20 stations. The distribution of above 10 numbers during night is as shown in the Table 2.9. During day only one station at 9°-70°00' recorded a maximum catch of 392 numbers. Nine stations yielded the catch of 20-100 numbers. The other stations showed low catch of less than 20 numbers. The distribution of above 10 numbers during day is as shown in the Table 2.10.

Table 2.8: *V. lucetia* more than 20 numbers (Pooled)

Sl.No.	Month	Stn.depth (m)	Lat	Long.	Opn.depth (m)	Time	No
1	September	4525	9°59'	70°01'	260	17.30-18.00	392
2	November	764	18°35'	70°17'	35-45	22.30-23.00	265
3	September	2440	20°55'	66°55'	40	20.30-21.00	200
4	September	2749	8°00'	75°00'	40	23.30-00.00	186
5	July	1835	12°30'	73°30'	50	21.20-21.50	162
6	November	3391	17°29'	60°21'	45	20.25-20.55	149
7	October	3359	17°23'	69°30'	60	5.00-5.30	107
8	November	2992	20°30'	68°21'	75	21.15-21.45	98
9	September	1937	13°01	72°57'	340	13.45-14.15	95
10	September	592.2	15°55'	71°35'	70-90	19.35-20.05	88
11	September	2171	6°36'	76°26'	30-40	21.15-21.45	80
12	September	1632	12°56'	71°52'	50	23.50-00.20	80
13	October	3870	16°25'	67°30'	60	16.00-16.30	72
14	October	4103	13°28'	67°30'	400	20.00-20.30	64
15	September	2405	13°00'	70°57'	320	8.25-8.55	63
16	October	3394	17°30'	67°24'	60	5.00-5.30	53
17	September	1980	10°00'	73°00'	350	7.45-8.15	53
18	November	3108	19°29'	67°29'	80	21.00-21.30	51
19	December	2000	8°34'	72°29'	100	20.45-21.15	50
20	October	4452	10°31'	68°32'	120	5.00-50.30	46
21	September	2618	15°00'	70°59'	40	22.30-23.00	45
22	November	1182	19°33'	69°20'	35	23.35-00.05	39
23	July	1584	12°30'	71°29'	60-70	5.25-5.55	38
24	September	3582	16°56'	68°54'	40	20.00-20.30	37
25	September	200	15°00'	73°00'	40	19.45-20.15	32
26	December	1778	10°29'	73°26'	100	23.10-23.40	31
27	November	3399	15°28'	70°26'	225	8.25-8.55	30
28	November	3451	16°27'	70°27'	3451	20.00-20.30	30
29	September	1188	20°56'	69°00'	40	23.40-00.10	30
30	September	3485	16°58'	69°59'	340-400	11.35-12.05	30
31	September	3646	10°00'	71°00'	280	17.30-18.00	23
32	November	1099	15°31'	71°38'	30	19.00-19.30	21
33	May	4181	8°00'	70°02'	90	20.00-20.30	21
34	September	3476	14°59'	70°01'	340	12.30-13.00	21
35	September	2665	21°00'	67°58'	280-300	17.10-17.40	20

Table 2.9: *V. lucetia* more than 10 numbers Night

Sl.No.	Month	Stn.depth (m)	Lat	Long.	Opn.depth (m)	Time	No
1	November	764	18°35'	70°17'	35-45	22.30-23.00	265
2	September	2440	20°55'	66°55'	40	20.30-21.00	200
3	September	2749	8°00'	75°00'	40	23.30-00.00	186
4	July	1835	12°30'	73°30'	50	21.20-21.50	162
5	November	3391	17°29'	60°21'	45	20.25-20.55	149
6	October	3359	17°23'	69°30'	60	5.00-5.30	107
7	November	2992	20°30'	68°21'	75	21.15-21.45	98
8	September	592.2	15°55'	71°35'	70-90	19.35-20.05	88
9	September	2171	6°36'	76°26'	30-40	21.15-21.45	80
10	September	1632	12°56'	71°52'	50	23.50-00.20	80
11	October	4103	13°28'	67°30'	400	20.00-20.30	64
12	October	3394	17°30'	67°24'	60	5.00-5.30	53
13	November	3108	19°29'	67°29'	80	21.00-21.30	51
14	December	2000	8°34'	72°29'	100	20.45-21.15	50
15	October	4452	10°31'	68°32'	120	5.00-50.30	46
16	September	2618	15°00'	70°59'	40	22.30-23.00	45
17	November	1182	19°33'	69°20'	35	23.35-00.05	39
18	July	1584	12°30'	71°29'	60-70	5.25-5.55	38
19	September	3582	16°56'	68°54'	40	20.00-20.30	37
20	September	200	15°00'	73°00'	40	19.45-20.15	32
21	December	1778	10°29'	73°26'	100	23.10-23.40	31
22	November	3451	16°27'	70°27'	3451	20.00-20.30	30
23	September	1188	20°56'	69°00'	40	23.40-00.10	30
24	November	1099	15°31'	71°38'	30	19.00-19.30	21
25	May	4181	8°00'	70°02'	90	20.00-20.30	21
26	November	968	16°14	72°15	100	19.15-19.45	18
27	September	2415	6°38'	77°31'	390-400	21.00-21.30	18
28	September	2415	6°38'	77°31'	30-40	22.05-22.35	18
29	May	1926	10°29'	73°30'	80-90	20.40-21.10	16
30	May	4189	12°59'	69°02'	250	6.30-7.00	16
31	October	3440	10°30'	70°26'	60	21.50-22.20	14
32	September	4229	13°00'	69°57'	40	21.30-22.00	13
33	May	1020	12°58'	72°04'	60	20.15-20.45	12
34	May	4530	9°59'	69°54'	180-190	19.40-20.10	10

Table 2.10: *V. lucetia* more than 10 numbers Day

Sl.No.	Month	Stn.depth (m)	Lat	Long.	Opn.depth (m)	Time	No
1	September	4525	9°59'	70°01'	260	17.30-18.00	392
2	September	1937	13°01	72°57'	340	13.45-14.15	95
3	October	3870	16°25'	67°30'	60	16.00-16.30	72
4	September	2405	13°00'	70°57'	320	8.25-8.55	63
5	September	1980	10°00'	73°00'	350	7.45-8.15	53
6	September	3485	16°58'	69°59'	340-400	11.35-12.05	30
7	November	3399	15°28'	70°26'	225	8.25-8.55	30
8	September	3646	10°00'	71°00'	280	17.30-18.00	23
9	September	3476	14°59'	70°01'	340	12.30-13.00	21
10	September	2665	21°00'	67°58'	280-300	17.10-17.40	20
11	May	2761	7°59'	75°03'	380-400	14.10-14.40	17
12	November	1741	17°30'	70°59'	20-Oct	13.00-13.30	16
13	October	3991	14°31'	67°32'	750	13.30-14.00	14

2.3.3.2 Spatial distribution

Generally the catch of *V. lucetia* was poor. The mean catch ranged between 3 and 68 numbers. Good catch pockets was located in Latitudes 18°, 17°,13° and 20°N.

Good concentration of 197 numbers was present in Lat. 9°N. The latitude 13° N also showed a good catch of 79 numbers. During night the numbers ranged from 4-197.

During day the area 17°-20°N was found to yield better results than other areas. The number /haul ranged between 5-109 numbers. (Figure 2.13)

2.3.3.3 Seasonal distribution

Contrary to *V. nimbaria*, *V. lucetia* was available in more abundance during monsoon (95 numbers). Post monsoon catch was 49 numbers and premonsoon season showed a poor catch of 12 numbers. The same trend was shown during night and day. (Figure 2.14)

2.3.3.4 Bathymetric distribution

2.3.3.4a Vertical distribution

In the operational depth the mean catch was more or less evenly distributed with slightly more at 0-50m depths. The night catches ranged between 15 and 71 numbers. The maximum catch was from the depth range of 0-50m. During day the highest catch of 62 numbers was from the depth range of 100-300m. The day catch ranged between 16 and 62 numbers (Figure 2.15).

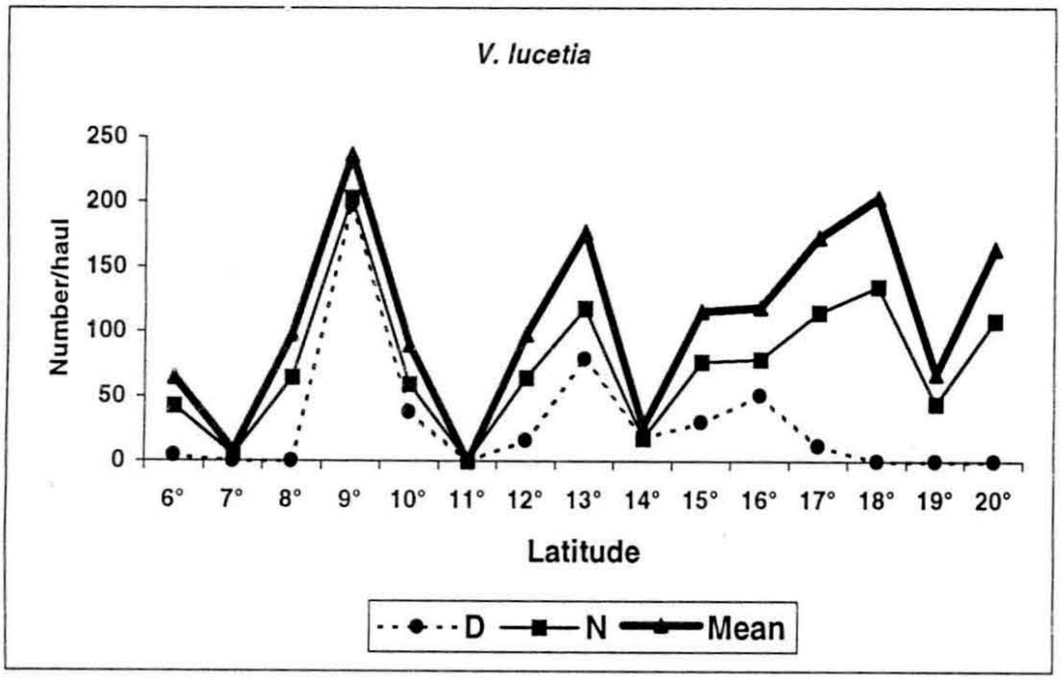


Figure 2.13 Spatial distribution of *V. lucetia.*

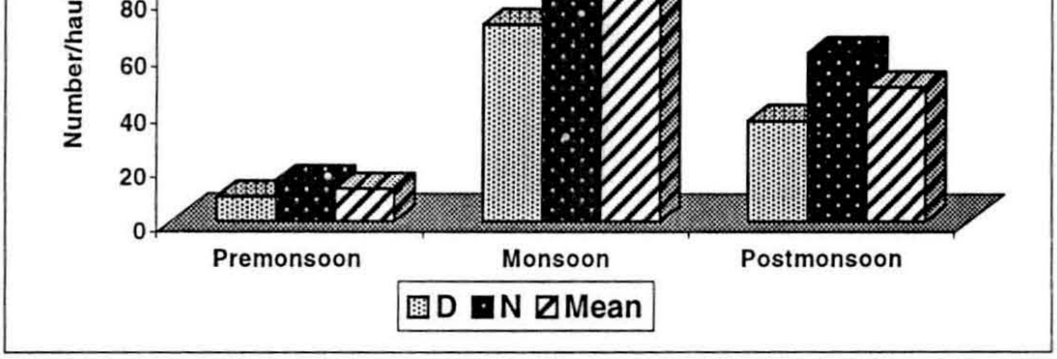


Figure. 2.14 Seasonal distribution of *V. lucetia*

2.3.3.4b Horizontal distribution

The horizontal distribution abundance was recorded between 34 and 55 numbers. The lower depth of 300-1000m showed a better result during night. A good catch during night was caught in the area above 3000m depth (67 numbers). (Figure 2.16)

2.3.3.5 Temporal distribution

Temporal studies in *V. lucetia* and *V. nimbaria* showed the same time of ascent and descent. From 4.00 hrs to 6.00 hrs were seen at the surface 0-100m. At 6.00-7.00hrs were observed at 0-100 m and 100-300m. From 7.00-17.00 hrs were observed below 300m. From 17-19.00 hrs all were seen from 100-300m. The ascent began at 19.00 hrs. From 22.00 hrs 100% were observed at the surface 0-100m . The descent to the deeper layers took place from morning 7.00 hrs. (Figure 2.17).

The Genus *Icthyococcus* represented by the species *I. ovatus* occurred only three times in the Samples examined in the west coast. They occurred at Latitudes 10°00 N, 6°09'N and 7°59'N in the southwest coast. The station depth at which they occurred was at 4514m, 2136m and 2768m. The operation depths at which they occurred were 380-400m during day in the southwest coast. The genus *Icthyococcus* occurred in May and September. Due to inavailability of samples the distributional study has not been done.

2.3.4 Biomass estimation

The Table 2.11 shows the biomass of the family Photichthyidae of more than 30 tonnes.The highest biomass of 1954 tonnes was recorded at station depth 2412m, operation depth 65m, Lat.17 °00'N and Long. 71°46'E. During day the biomass ranged from 25 tonnes to 773 tonnes (Table 2.12). During night the biomass varied from 4 tonnes to 2120 tonnes (Table 2.13). The northwest coast showed a higher

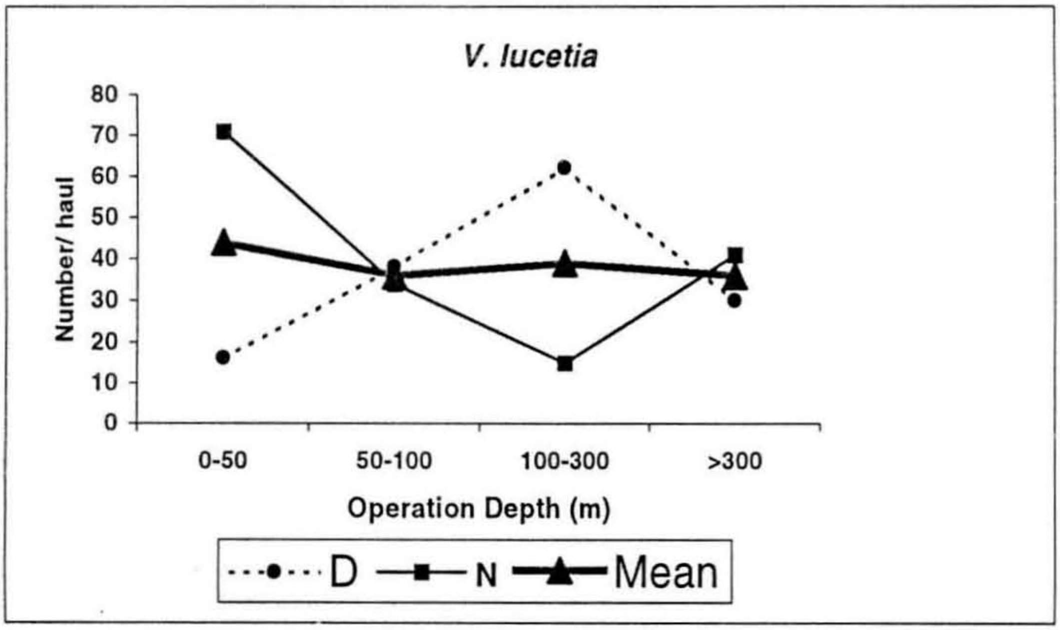


Figure. 2.15 Vertical distribution of *V. lucetia*

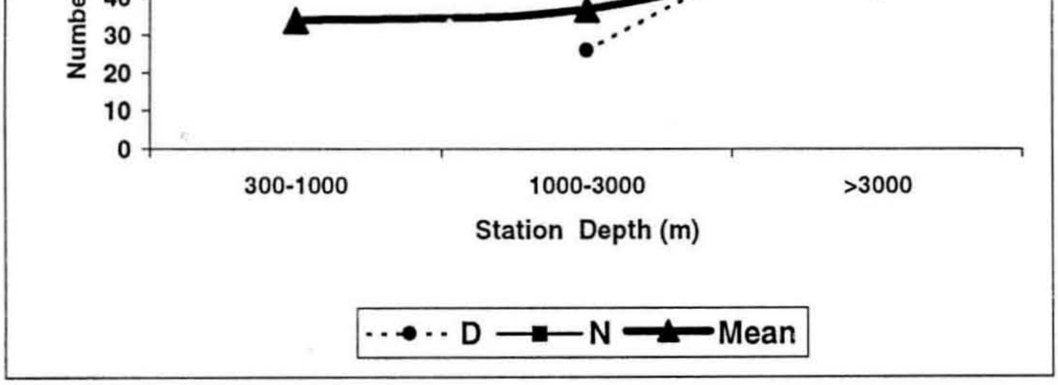


Figure. 2.16 Horizontal distribution of *V. lucetia*

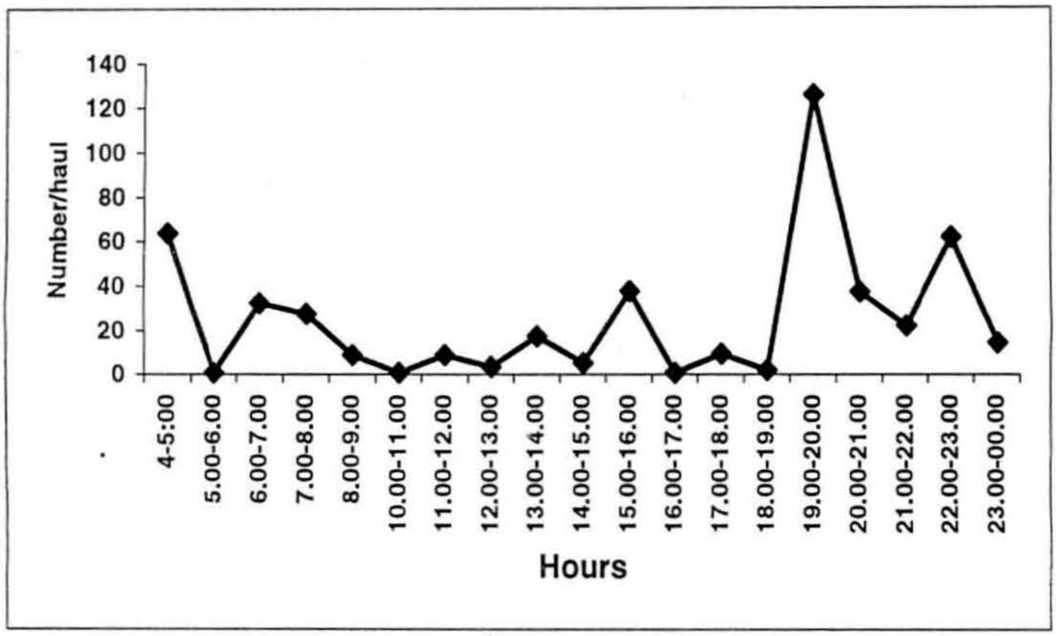


Figure. 2.17 Temporal distribution of *V. lucetia*

biomass than the southwest coast of the Indian EEZ. The spatial biomass is as seen in Table 2.14.

Monthly a high biomass was recorded during March (1507 tonnes) and the lowest biomass was recorded at July (35 tonnes). (Figure 2.18). Seasonally premonsoon recorded a biomass of 834 tonnes followed by postmonsoon at 194 tonnes and monsoon recorded a biomass of 150 tonnes.

Bathymetrically at vertical depths of 50-100mm a high biomass of 467 tonnes was seen. During day the highest biomass was at 100-300m (504 tonnes) and at night a biomass was recorded at 50-100m (842 tonnes) and 0- 50m (524 tonnes) (Figure 2.19). Horizontal depth showed a high biomass of 300-1000m (1859 tonnes). At day and night a high biomass was seen at 300-1000m at 828 tonnes and 2891 tonnes respectively. (Figure 2.20).

2.3.4.1 *V. nimbaria*

The biomass in tonnes of *V. nimbaria* more than 30 tonnes is as shown in Table 2.15. The highest biomass of 1954 tonnes was recorded at station depth 2412m, operation depth 65m, Lat.17 °00'N and Long. 71°46'E at 17.20 to 17.50 hours. The Table 2.16 and Table 2.17 shows the biomass (Tonnes in 1°square) for night and day respectively.

2.3.4.2 *V.lucetia*

The biomass in tonnes of *V. lucetia* more than 30 tonnes is as shown in Table 2.18. The highest biomass of 5789 tonnes was recorded at station depth 4525 m, operation depth 260m, Lat.9 °00' and Long. 70°01' at 17.30 to 18.00 hours. The Table 2.19 and Table 2.20 shows the biomass (Tonnes1°square) for night and day respectively.

Table 2.11 Estimated Biomass of Photichthyidae of more than 30 tonnes during day and night

Sl.No.	Month	Stn. depth (m)	Opn. depth (m)	Lat	Long.	Tonnes
1	March	2412	65	17°00'	70°59'	6624.13
2	March	1018	75	20°59'	68°58'	5121.18
3	March	2382	35	21°00'	66°59'	3755.53
4	March	2766	310	20°58'	67°57'	2182.07
5	April	1199	150-200	17°00'	71°46'	1954.46
6	April	792	300	12°34	74°06'	1246.9
7	November	764	35-45	18°35'	70°17'	884.45
8	May	2415	390-400	6°38'	77°31'	866
9	September	2749	40	8°00'	75°00'	804.05
10	October	431	300	12°29'	74°09'	727.36
11	March	3539	190	16°59'	68°00'	723.03
12	March	2809	320	16°59'	68°00'	702.62
13	April	616	75	15°47'	72°40'	579
14	April	4525	260	9°59'	70°01'	578.92
15	May	2419	70	21°00'	66°00'	484.9
16	December	2770	40-50	8°00'	74°04'	445.32
17	December	3582	40	16°56'	68°54'	425.53
18	May	2171	30-40	6°36'	76°26'	378.52
19	November	108	50	21°26'	68°30'	311.72
20	May	1333.5	280	17°22'	71°10'	278.33
21	October	4103	400	13°28'	67°30'	272.14
22	October	3870	60	16°25'	67°30'	269.67
23	November	3391	45	17°29'	60°21'	267.19
24	November	229	15-35	15°19	72°52'	247
25	October	3394	60	17°30'	67°24'	189.26
26	March	3250	320	19°03'	67°01'	160.81
27	November	1741	20-Oct	17°30'	70°59'	148.44
28	October	3991	750	14°31'	67°32'	143.49
29	December	1632	50	12°56'	71°52'	138.54
30	April	395	180	12°28'	74°09'	133.6
31	December	1778	100	10°29'	73°26'	131.12
32	September	1980	350	10°00'	73°00'	113.8
33	December	2440	40	20°55'	66°55'	98.96
34	September	2768	400	7°59'	74°02'	98.96
35	March	254	50	16°59'	68°00'	95.87
36	December	2000	100	8°34'	72°29'	89.06
37	December	2618	40	15°00'	70°59'	89.06
38	May	2770	30-50	20°27'	67°29'	89.06
39	November	2651	260	17°30'	70°29'	89.06
40	November	3179	130-135	19°29'	68°30'	81.64
41	December	4229	40	13°00'	69°57'	78.16
42	April	657	75	18°00'	70°43'	78
43	November	1182	35	19°33'	69°20'	68.03
44	December	200	40	15°00'	73°00'	66.8
45	October	3359	60	17°23'	69°30'	66.8
46	November	3108	80	19°29'	67°29'	55.67
47	May	1926	80-90	10°29'	73°30'	53.81
48	December	3485	340-400	16°58'	69°59'	49.48
49	November	2992	75	20°30'	68°21'	45.77
50	March	227	185	16°59'	71°51'	44.53
51	May	1020	60	12°58'	72°04'	44.53
52	May	4181	90	8°00'	70°02'	44.53
53	November	968	100	16°14	72°15	44.53
54	September	2415	30-40	6°38'	77°31'	44.53
55	May	1864	50	8°30'	73°32'	43.29
56	May	4633	250-300	7°59'	69°02'	43.29
57	December	2665	280-300	21°00'	67°58'	39.58
58	November	1120	350	10°19	75°28'	37.11
59	July	3451	3451	16°27'	70°27'	35.87
60	October	4290	750	11°26'	67°54'	30.31

Table 2.12 Estimated Biomass at day of family Photichthyidae

Sl.No.	Stn. depth (m)	Opn. depth (m)	Lat	Long.	Tonnes
1	1199	200	17°00'	71°46'	1954.46
2	792	300	12°34	74°06'	1246.9
3	431	300	12°29'	74°09'	727.36
4	2809	320	16°59'	68°00'	702.62
5	4525	260	9°59'	70°01'	578.92
6	108	50	21°26'	68°30'	311.72
7	1333.5	280	17°22'	71°10'	278.33
8	3250	320	19°03'	67°01'	160.81
9	3991	750	14°31'	67°32'	143.49
10	1980	350	10°00'	73°00'	113.8
11	2768	400	7°59'	74°02'	98.96
12	254	50	16°59'	68°00'	95.87
13	270	50	20°27'	67°29'	89.06
14	2651	260	17°30'	70°29'	89.06
15	3179	135	19°29'	68°30'	81.64
16	3485	400	16°58'	69°59'	49.48
17	227	185	16°59'	71°51'	44.53
18	4633	300	7°59'	69°02'	43.29
19	2665	300	21°00'	67°58'	39.58
20	1120	350	10°19	75°28'	37.11
21	4290	750	11°26'	67°54'	30.31

Table 2.13 Estimated Biomass at night of family Photichthyidae

Sl.No.	Stn. depth (m)	Opn. depth (m)	Lat	Long.	Tonnes
1	2412	65	17°00'	70°59'	6624.13
2	1018	75	20°59'	68°58'	5121.18
3	2382	35	21°00'	66°59'	3755.53
4	2766	310	20°58'	67°57'	2182.07
5	764	45	18°35'	70°17'	884.45
6	2415	400	6°38'	77°31'	866
7	2749	40	8°00'	75°00'	804.05
8	3539	190	16°59'	68°00'	723.03
9	616	75	15°47'	72°40'	579
10	2419	70	21°00'	66°00'	484.9
11	2770	50	8°00'	74°04'	445.32
12	3582	40	16°56'	68°54'	425.53
13	2171	40	6°36'	76°26'	378.52
14	4103	400	13°28'	67°30'	272.14
15	3870	60	16°25'	67°30'	269.67
16	3391	45	17°29'	60°21'	267.19
17	229	35	15°19	72°52'	247
18	3394	60	17°30'	67°24'	189.26
19	1741	20	17°30'	70°59'	148.44
20	1632	50	12°56'	71°52'	138.54
21	395	180	12°28'	74°09'	133.6
22	1778	100	10°29'	73°26'	131.12
23	2440	40	20°55'	66°55'	98.96
24	2000	100	8°34'	72°29'	89.06
25	2618	40	15°00'	70°59'	89.06
26	4229	40	13°00'	69°57'	78.16
27	657	75	18°00'	70°43'	78
28	1182	35	19°33'	69°20'	68.03
29	200	40	15°00'	73°00'	66.8
30	3359	60	17°23'	69°30'	66.8
31	3108	80	19°29'	67°29'	55.67
32	1926	90	10°29'	73°30'	53.81
33	2992	75	20°30'	68°21'	45.77
34	968	100	16°14	72°15	44.53
35	1020	60	12°58'	72°04'	44.53
36	2415	40	6°38'	77°31'	44.53
37	4181	90	8°00'	70°02'	44.53
38	1864	50	8°30'	73°32'	43.29
39	3451	50	16°27'	70°27'	35.87

Table 2.14 Spatial Biomass in tonnes of family Photichthyidae

Latitude	Day	Night	Mean
10°	35.62	34.28	34.95
11°	30.31		15.16
12°	500.21	49.48	274.85
13°	27.21	117.63	72.42
14°	143.49		71.75
15°	25.62	165.29	95.46
16°	150.71	299.72	225.22
17°	773.95	1218.24	996.10
18°	0.78	251.13	125.96
19°	121.22	61.85	91.54
20°	89.06	1245.85	667.46
21°	175.65	2120.21	1147.93
6°	29.69	429.98	229.84
7°	42.98	4.89	23.94
8°	4.95	285.25	145.10
9°	202.45	4	103.23

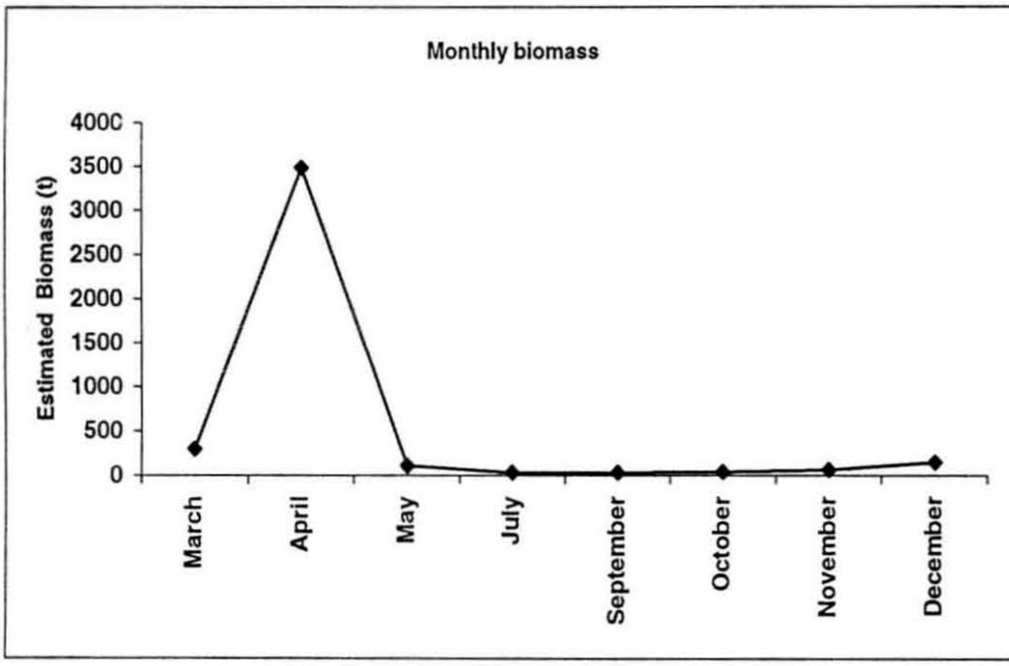


Figure 2.18 Monthly biomass of family Photichthyidae

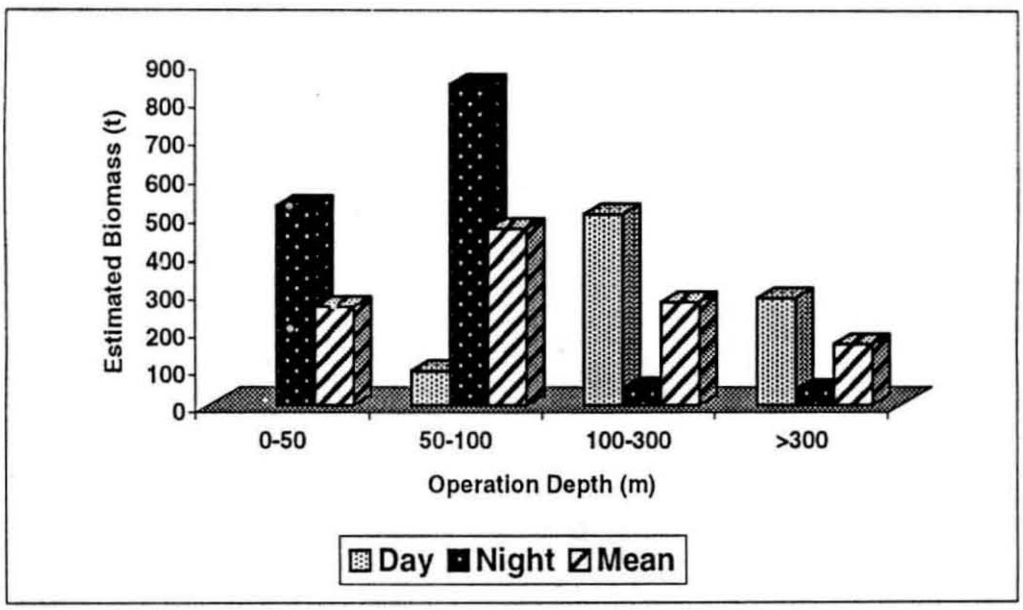


Figure 2.19 Vertical biomass of family Photichthyidae

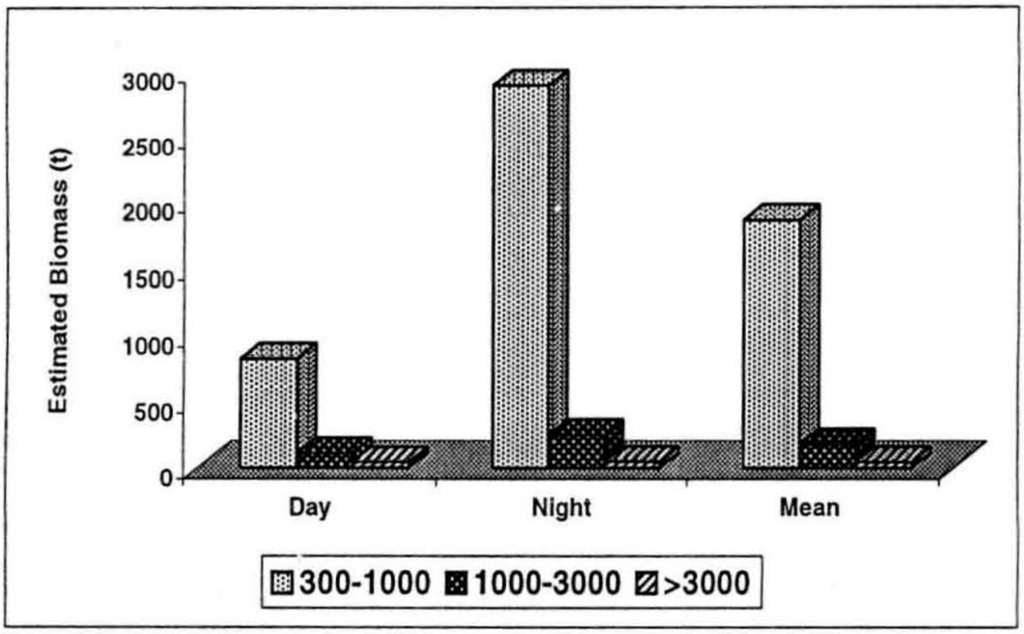


Figure 2.20 Horizontal biomass of family Photichthyidae

Table 2.15 Estimated Biomass of *V. nimbaria* more than 30 tonnes (day and night)

Sl.No.	Month	Stn. depth (m)	Lat	Long	Opn. depth (m)	Time	Tonnes
1	April	1199	17°00'	71°46'	150-200	17.20-17.50	1954.46
2	April	792	12°34	74°06'	300	7.10-7.40	1246.896
3	April	431	12°29'	74°09'	300	7.10-7.40	727.356
4	April	616	15°47'	72°40'	75	19.45-20.15	578.916
5	September	4525	9°59'	70°01'	260	17.30-18.00	578.916
6	May	2770	8°00'	74°04'	40-50	21.45-22.15	445.32
7	October	4290	11°26'	67°54'	750	14.50-15.20	307.3945
8	May	1333.5	17°22'	71°10'	280	15.45-16.15	278.325
9	November	764	18°35'	70°17'	35-45	22.30-23.00	216.475
10	September	2749	8°00'	75°00'	40	23.30-00.00	185.55
11	November	3391	17°29'	60°21'	45	20.25-20.55	178.128
12	October	3991	14°31'	67°32'	750	13.30-14.00	143.492
13	October	4103	13°28'	67°30'	400	20.00-20.30	136.07
14	April	395	12°28'	74°09'	180	19.00-19.30	133.596
15	October	3870	16°25'	67°30'	60	16.00-16.30	126.174
16	September	1980	10°00'	73°00'	350	7.45-8.15	113.804
17	September	2768	7°59'	74°02'	400	13.10-13.40	98.96
18	October	3394	17°30'	67°24'	60	5.00-5.30	94.6305
19	November	2651	17°30'	70°29'	260	21.15-21.45	89.064
20	December	2440	20°55'	66°55'	40	20.30-21.00	69.272
21	December	3582	16°56'	68°54'	40	20.00-20.30	69.272
22	April	657	18°00'	70°43'	75	5.05-5.35	66.798
23	December	1778	10°29'	73°26'	100	23.10-23.40	59.376
24	December	3485	16°58'	69°59'	340-400	11.35-12.05	49.48
25	May	1926	10°29'	73°30'	80-90	20.40-21.10	43.9135
26	May	4633	7°59'	69°02'	250-300	8.00-8.30	43.295
27	December	1632	12°56'	71°52'	50	23.50-00.20	39.584
28	December	2665	21°00'	67°58'	280-300	17.10-17.40	39.584
29	April	1120	10°19	75°28'	350	14.50-15.20	37.11
30	May	1020	12°58'	72°04'	60	20.15-20.45	35.873
31	May	1864	8°30'	73°32'	50	20.50-21.20	34.636
32	September	2415	6°38'	77°31'	390-400	21.00-21.30	34.636

Table 2.16 Estimated Biomass of *V. nimbaria* during night of more than 30 tonnes

Sl.No.	Month	Stn. depth (m)	Lat	Long	Opn. depth (m)	Time	Tonnes
1	April	616	15°47'	72°40'	75	19.45-20.15	578.916
2	May	2770	8°00'	74°04'	40-50	21.45-22.15	445.32
3	November	764	18°35'	70°17'	35-45	22.30-23.00	216.475
4	September	2749	8°00'	75°00'	40	23.30-00.00	185.55
5	November	3391	17°29'	60°21'	45	20.25-20.55	178.128
6	October	4103	13°28'	67°30'	400	20.00-20.30	136.07
7	April	395	12°28'	74°09'	180	19.00-19.30	133.596
8	October	3394	17°30'	67°24'	60	5.00-5.30	94.6305
9	November	2651	17°30'	70°29'	260	21.15-21.45	89.064
10	December	2440	20°55'	66°55'	40	20.30-21.00	69.272
11	December	3582	16°56'	68°54'	40	20.00-20.30	69.272
12	April	657	18°00'	70°43'	75	5.05-5.35	66.798
13	December	1778	10°29'	73°26'	100	23.10-23.40	59.376
14	May	1926	10°29'	73°30'	80-90	20.40-21.10	43.9135
15	December	1632	12°56'	71°52'	50	23.50-00.20	39.584
16	May	1020	12°58'	72°04'	60	20.15-20.45	35.873
17	May	1864	8°30'	73°32'	50	20.50-21.20	34.636
18	September	2415	6°38'	77°31'	390-400	21.00-21.30	34.636

Table 2.17: Estimated Biomass of more than 30 tonnes during day

Sl.No.	Month	Stn. depth (m)	Lat	Long	Opn. depth (m)	Time	Tonnes
1	April	1199	17°00'	71°46'	150-200	17.20-17.50	1954.46
2	April	792	12°34	74°06'	300	7.10-7.40	1246.896
3	April	431	12°29'	74°09'	300	7.10-7.40	727.356
4	September	4525	9°59'	70°01'	260	17.30-18.00	578.916
5	October	4290	11°26'	67°54'	750	14.50-15.20	307.3945
6	May	1333.5	17°22'	71°10'	280	15.45-16.15	278.325
7	October	3991	14°31'	67°32'	750	13.30-14.00	143.492
8	October	3870	16°25'	67°30'	60	16.00-16.30	126.174
9	September	1980	10°00'	73°00'	350	7.45-8.15	113.804
10	September	2768	7°59'	74°02'	400	13.10-13.40	98.96
11	December	3485	16°58'	69°59'	340-400	11.35-12.05	49.48
12	May	4633	7°59'	69°02'	250-300	8.00-8.30	43.295
13	December	2665	21°00'	67°58'	280-300	17.10-17.40	39.584
14	April	1120	10°19	75°28'	350	14.50-15.20	37.11

Table 2.18 Estimated Biomass of *V. lucetia* more than 30 tonnes (Pooled)

Sl.No.	Month	Stn. depth (m)	Lat	Long	Opn. depth (m)	Time	Tonnes (t)
1	September	4525	9°59'	70°01'	260	17.30-18.00	5789.16
2	November	764	18°35'	70°17'	35-45	22.30-23.00	667.98
3	September	2749	8°00'	75°00'	40	23.30-00.00	618.5
4	September	1980	10°00'	73°00'	350	7.45-8.15	398.314
5	September	2171	6°36'	76°26'	30-40	21.15-21.45	378.522
6	September	3582	16°56'	68°54'	40	20.00-20.30	356.256
7	September	2440	20°55'	66°55'	40	20.30-21.00	326.568
8	October	4103	13°28'	67°30'	400	20.00-20.30	326.568
9	September	592.2	15°55'	71°35'	70-90	19.35-20.05	267.192
10	October	3394	17°30'	67°24'	60	5.00-5.30	252.348
11	September	2405	13°00'	70°57'	320	8.25-8.55	197.92
12	October	3870	16°25'	67°30'	60	16.00-16.30	143.492
13	November	1741	17°30'	70°59'	20-Oct	13.00-13.30	136.07
14	September	3646	10°00'	71°00'	280	17.30-18.00	123.7
15	May	4633	7°59'	69°02'	250-300	8.00-8.30	123.7
16	November	3399	15°28'	70°26'	225	8.25-8.55	111.33
17	September	1632	12°56'	71°52'	50	23.50-00.20	98.96
18	November	3391	17°29'	60°21'	45	20.25-20.55	89.064
19	September	3485	16°58'	69°59'	340-400	11.35-12.05	86.59
20	September	1937	13°01	72°57'	340	13.45-14.15	79.168
21	September	2665	21°00'	67°58'	280-300	17.10-17.40	79.168
22	September	4229	13°00'	69°57'	40	21.30-22.00	79.168
23	December	2000	8°34'	72°29'	100	20.45-21.15	71.746
24	December	1778	10°29'	73°26'	100	23.10-23.40	71.746
25	September	2618	15°00'	70°59'	40	22.30-23.00	69.272
26	September	2415	6°38'	77°31'	390-400	21.00-21.30	69.272
27	September	200	15°00'	73°00'	40	19.45-20.15	66.798
28	October	3359	17°23'	69°30'	60	5.00-5.30	61.85
29	May	2761	7°59'	75°03'	380-400	14.10-14.40	51.954
30	November	1182	19°33'	69°20'	35	23.35-00.05	46.3875
31	September	1188	20°56'	69°00'	40	23.40-00.10	44.532
32	November	968	16°14	72°15	100	19.15-19.45	44.532
33	September	2415	6°38'	77°31'	30-40	22.05-22.35	44.532
34	September	3476	14°59'	70°01'	340	12.30-13.00	39.584
35	November	2992	20°30'	68°21'	75	21.15-21.45	35.873
36	October	3991	14°31'	67°32'	750	13.30-14.00	34.636

Table 2.19 Estimated Biomass of *V. lucetia* more than 30 tonnes Night

Sl.No.	Month	Stn. depth (m)	Lat	Long	Opn. depth (m)	Time	Tonnes (t)
1	November	764	18°35'	70°17'	35-45	22.30-23.00	667.98
2	September	2749	8°00'	75°00'	40	23.30-00.00	618.5
3	September	2171	6°36'	76°26'	30-40	21.15-21.45	378.522
4	September	3582	16°56'	68°54'	40	20.00-20.30	356.256
5	September	2440	20°55'	66°55'	40	20.30-21.00	326.568
6	October	4103	13°28'	67°30'	400	20.00-20.30	326.568
7	September	592.2	15°55'	71°35'	70-90	19.35-20.05	267.192
8	October	3394	17°30'	67°24'	60	5.00-5.30	252.348
9	September	1632	12°56'	71°52'	50	23.50-00.20	98.96
10	November	3391	17°29'	60°21'	45	20.25-20.55	89.064
11	September	4229	13°00'	69°57'	40	21.30-22.00	79.168
12	December	2000	8°34'	72°29'	100	20.45-21.15	71.746
13	December	1778	10°29'	73°26'	100	23.10-23.40	71.746
14	September	2618	15°00'	70°59'	40	22.30-23.00	69.272
15	September	2415	6°38'	77°31'	390-400	21.00-21.30	69.272
16	September	200	15°00'	73°00'	40	19.45-20.15	66.798
17	October	3359	17°23'	69°30'	60	5.00-5.30	61.85
18	November	1182	19°33'	69°20'	35	23.35-00.05	46.3875
19	September	1188	20°56'	69°00'	40	23.40-00.10	44.532
20	November	968	16°14	72°15	100	19.15-19.45	44.532
21	September	2415	6°38'	77°31'	30-40	22.05-22.35	44.532
22	November	2992	20°30'	68°21'	75	21.15-21.45	35.873

Table 2.20 Estimated Biomass of *V. lucetia* more than 30 Tonnes at Day

Sl.No.	Month	Stn. depth (m)	Lat	Long	Opn. depth (m)	Time	Tonnes (t)
1	September	4525	9°59'	70°01'	260	17.30-18.00	5789.16
2	September	1980	10°00'	73°00'	350	7.45-8.15	398.314
3	September	2405	13°00'	70°57'	320	8.25-8.55	197.92
4	October	3870	16°25'	67°30'	60	16.00-16.30	143.492
5	November	1741	17°30'	70°59'	20	13.00-13.30	136.07
6	September	3646	10°00'	71°00'	280	17.30-18.00	123.7
7	May	4633	7°59'	69°02'	250-300	8.00-8.30	123.7
8	November	3399	15°28'	70°26'	225	8.25-8.55	111.33
9	September	3485	16°58'	69°59'	340-400	11.35-12.05	86.59
10	September	1937	13°01	72°57'	340	13.45-14.15	79.168
11	September	2665	21°00'	67°58'	280-300	17.10-17.40	79.168
12	May	2761	7°59'	75°03'	380-400	14.10-14.40	51.954
13	September	3476	14°59'	70°01'	340	12.30-13.00	39.584
14	October	3991	14°31'	67°32'	750	13.30-14.00	34.636

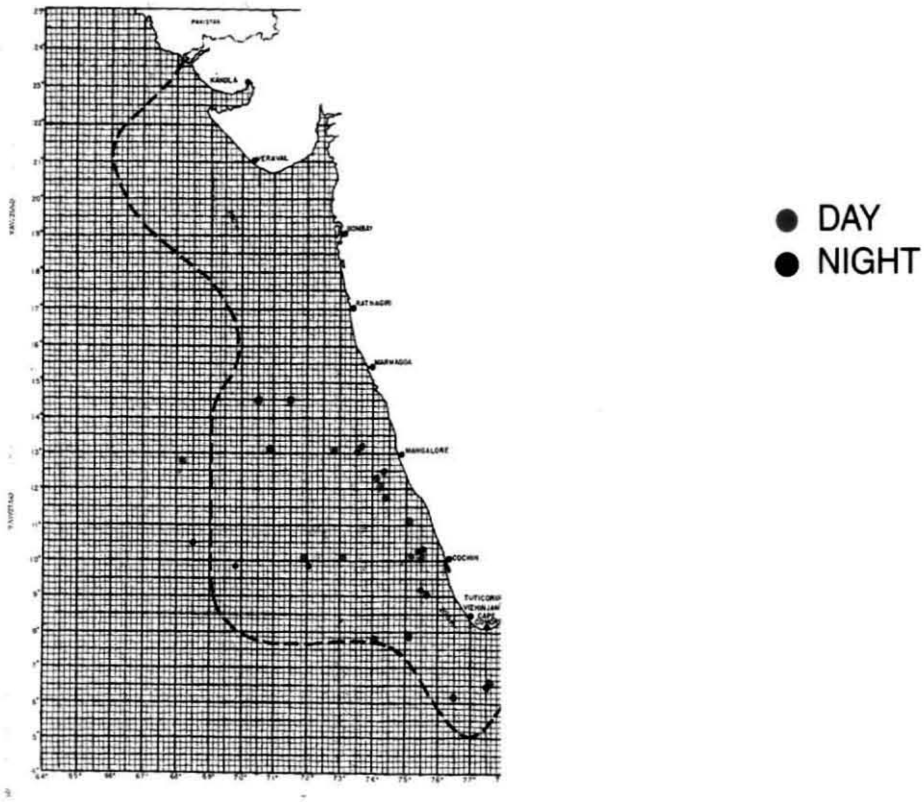


Figure 2.21 Day & Night occurrence of family sternoptychidae in the west coast

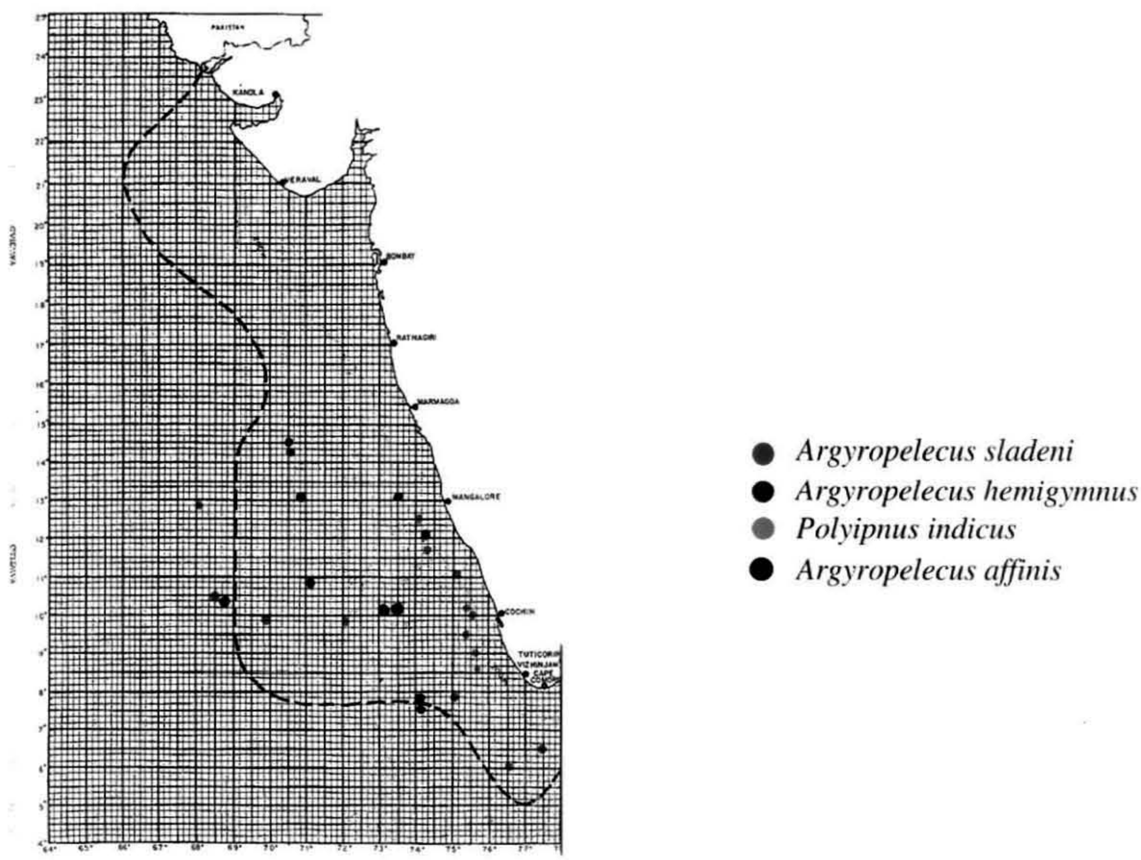


Figure 2.22 Species distribution of family sternoptychidae in the west coast

2.3.5 Family Sternoptychidae

2.3.5.1 General distribution

In the present study family Sternoptychidae with two genus i.e., *Argyropelecus* and *Polyipnus* with four species, *Argyropelecus sladeni, Argyropelecus hemigymnus, Argyropelecus affinis* and *Polyipnus indicus* was encountered in the west coast. (Figure 2.22). The IKMT recorded family Sternoptychidae in 31 stations in the west coast of India during the period of observation. (Table 2.21) The day and night occurrence of family Sternoptychidae is shown in Figure 2.21. The total number of the family Sternoptychidae seen in Day was 199 numbers and the number seen in Night was 31. The highest catch of family Sternoptychidae in numbers was 47 numbers at Lat.9°30'N and Long. 75°20'E in the operational depth of 150m and station depth of 958m. Only 7 stations yield more than 10 numbers. The vertical depths during day varied from 80-750m and station depths varied from 345-3646m. During night collections the vertical depths varied from 50-400m and station depths varied from 1048-4452m. The family sternoptychidae though it forms a small percentage in the total DSL nekton they are important as they play a significant role in the trophic relations in the oceans.

2.3.5.2 Diurnal catch

In the period of study of twelve cruises there were 21-day stations. The number /haul varied from 1-47 numbers. The highest catch was recorded during day. (Table 2.22). During night hauls there were only 6 stations that recorded Sternoptychidae. The number /haul varied between 1-12 numbers. The data is as shown in the Table.2.23. The day and night occurrence percent is shown in Figure 2.23.

Table 2.21: Day and Night combined data of family Sternoptychidae

Sl.No.	Month	Time	D/N	Lat.	Long.	Stn. depth (m)	Opn. depth (m)	No
1	October	8.00-8.30	D	9°30'	75°01'	958	150	47
2	April	17.45-18.15	D	10°00'	75°32'	573	330	32
3	October	7.45-8.15	D	10°00'	73°00'	1980	350	26
4	April	7.10-7.40	D	12°34'	74°06'	792	300	17
5	October	17.30-18.00	D	10°00'	71°80'	3646	280	13
6	June	19.40-20.10	N	13°01'	73°37'	1048	75	12
7	May	14.10-14.40	D	7°59'	75°03'	2761	380-400	9
8	April	7.25-7.55	D	9°04'	75°45'	345	260	7
9	May	20.00-20.30	N	9°59'	72°01'	2403	210	6
10	April	17.40-18.10	D	9°12'	75°44'	532	310	6
11	Dec	8.25-8.55	D	13°00	70°57'	2405	320	5
12	April	7.10-7.40	D	12°29'	74°09'	431	300	4
13	October	21.00-21.30	N	6°38'	77°31'	2415	390-400	4
14	June	17.10-17.40	D	11°49'	74°26'	382	280	3
15	April	18.40-19.15	D	13°09'	73°40'	531	370	3
16	May	11.15-11.45	D	12°54'	68°04'	4186	400	3
17	October	7.45-8.16	D	10°00'	73°00'	1980	350	3
18	October	5.00-5.30	N	10°31'	68°32'	4452	120	2
19	May	19.40-20.10	N	9°59'	69°54'	4530	180	2
20	June	7.10-7.40	D	11°03'	75°01'	620	270	2
21	June	7.50-8.20	D	12°02'	74°19'	531	320	2
22	October	16.00-16.30	D	6°09'	76°31'	2415	400	4
23	April	14.50-15.20	D	10°19'	75°28'	1120	350	2
24	May	19.40-20.10	N	9°59'	69°54'	4530	180	2
25	October	13.10-13.40	D	7°59'	74°02'	2768	400	4
26	Dec	13.45-14.15	D	13°01'	72°57'	1937	340	1
27	October	13.30-14.00	D	14°31'	17°32'	3991	750	1
28	April	21.00-21.30	N	10°16'	75°29'	1089	50	1
29	October	13.10-13.40	D	7°59'	74°02'	2768	400	1
30	October	13.30-14.50	D	14°31'	70°32'	3991	750	1
31	May	14.10-14.40	D	7°59'	75°03'	2762	380-400	9

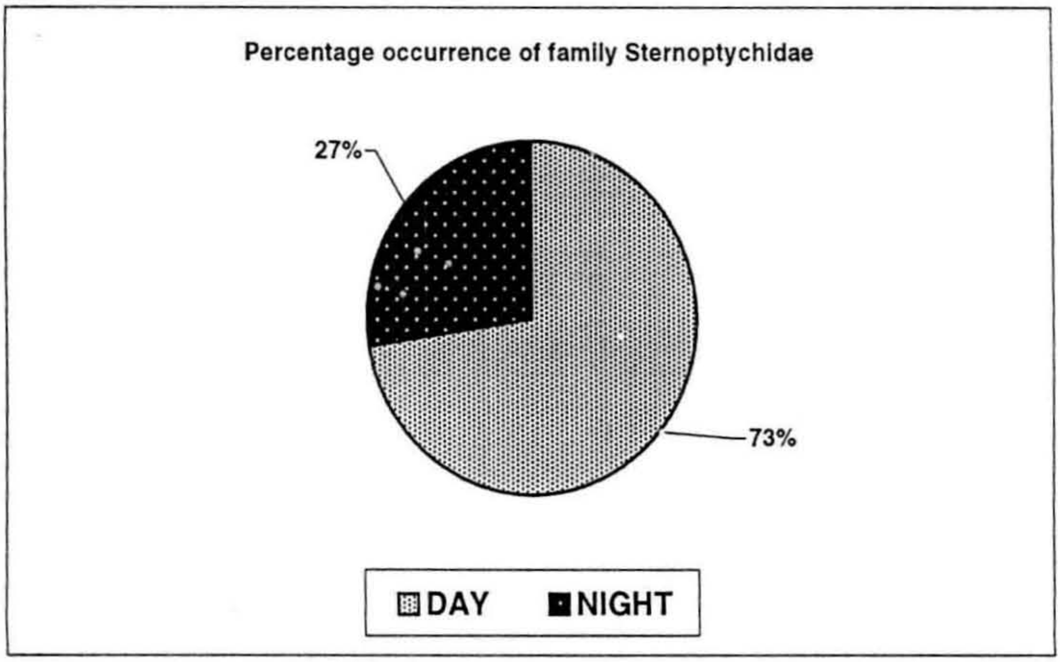


Figure 2.23 Percentage occurrence of family Sternoptychidae

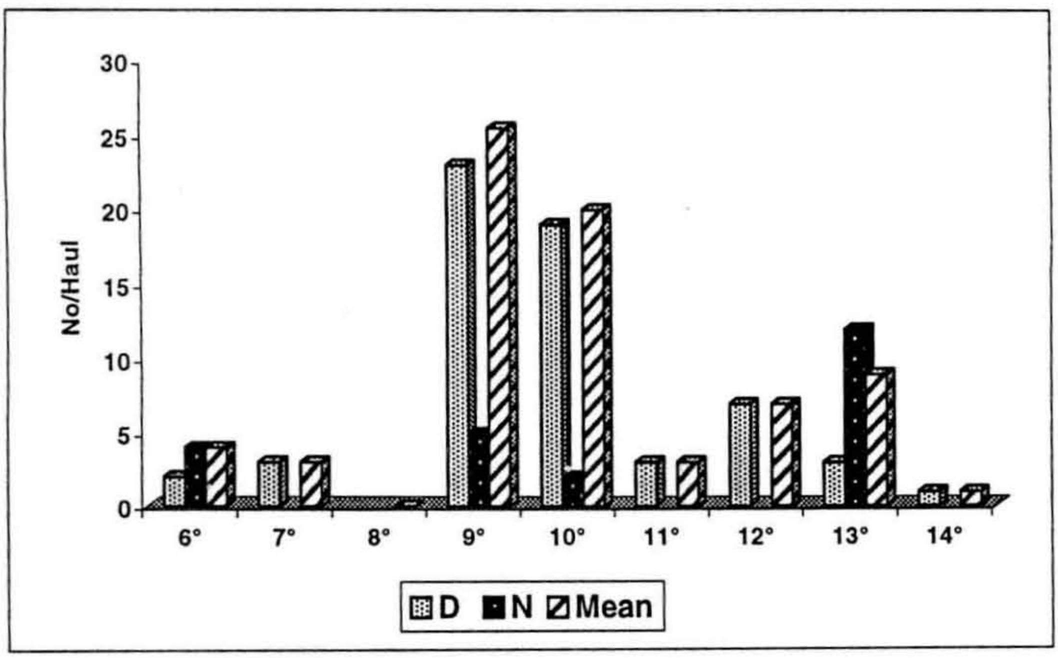


Figure 2.24 Spatial occurrence of family Sternoptychidae

Table 2.22: Day Distribtion data of family Sternoptychidae

Sl.No.	Month	Time	Lat	Long	Stn. depth (m)	Opn depth (m)	No
1	October	8.00-8.30	9°30'	75°01'	958	150	47
2	April	17.45-18.15	10°00'	75°32'	573	330	32
3	October	7.45-8.15	10°00'	73°00'	1980	350	29
4	April	7.10-7.40	12°34'	74°06'	792	300	17
5	October	17.30-18.00	10°00'	71°80'	3646	280	13
6	May	14.10-14.40	7°59'	75°03'	2761	380-400	9
7	April	7.25-7.55	9°04'	75°45'	345	260	7
8	April	17.40-18.10	9°12'	75°44'	532	310	6
9	Dec	8.25-8.55	13°00	70°57'	2405	320	5
10	April	7.10-7.40	12°29'	74°09'	431	300	4
11	October	16.00-16.30	6°09'	76°31'	2415	400	4
12	October	13.10-13.40	7°59'	74°02'	2768	400	4
13	April	18.40-19.15	13°09'	73°40'	531	370	3
14	June	17.10-17.40	11°49'	74°26'	382	280	3
15	May	11.15-11.45	12°54'	68°04'	4186	400	3
16	June	7.50-8.20	12°02'	74°19'	531	320	2
17	June	7.10-7.40	11°03'	75°01'	620	270	2
18	April	14.50-15.20	10°19'	75°28'	1120	350	2
19	Dec	13.45-14.15	13°01'	72°57'	1937	340	1
20	October	13.30-14.50	14°31'	70°32'	3991	750	1
21	October	13.30-14.00	14°31'	17°32'	3991	750	1
22	October	13.10-13.40	7°59'	74°02'	2768	400	1

Table 2.23 Distribution of family Sternoptychidae at Night.

Sl.No.	Month	Time	Lat	Long.	Stn depth (m)	Opn depth (m)	No
1	June	19.40-20.10	13°01'	73°37'	1048	75	12
2	May	20.00-20.30	9°59'	72°01'	2403	210	6
3	May	19.40-20.10	9°59'	69°54'	4530	180	4
4	October	21.00-21.30	6°38'	77°31'	2415	390-400	4
5	October	5.00-5.30	10°31'	68°32'	4452	120	2
6	April	21.00-21.30	10°16'	75°29'	1089	50	1

2.3.5.3 Spatial distribution

The number/haul during day ranged from 1-23 numbers and during night ranged from 1-12 numbers. At Latitudes 9°N, 10°N and 13°N higher numbers of family Sternoptychidae were seen. (Figure 2.24)

2.3.5.4 Month-wise distribution

High numbers were recorded during April (41 numbers), September (24 numbers) and October (26 numbers) . High numbers were recorded during day when compared to night. The day and night hauls monthwise is as shown in Figure 2.25.

2.3.5.5 Bathymetric distribution

Depth wise analysis showed that during day all the catches were recorded at 100-300m and above 300m-operation depth. During day a higher catch of 100 and 104 numbers were recorded from 100-300m and at depths greater than 300m. At night only 12 numbers were recorded at 50-100m and 12 numbers were at 100-300m-operation depth. (Figure 2.26) At station depths they were seen at higher numbers at 300-1000m (75numbers) and 1000-3000m. During day they was a higher occurrence at 300-1000m. At night high catches were at 1000-3000m. (Figure 2.27).

2.3.5.6 Temporal distribution

The temporal distribution of the family Sternoptychidae showed that they remained at depths greater than 500m both during day and night. (Figure 2.28).The fishes of the family Sternoptychidae were caught at high numbers during day and at lesser number during night. They are seen to exhibit very little or no diurnal migration.

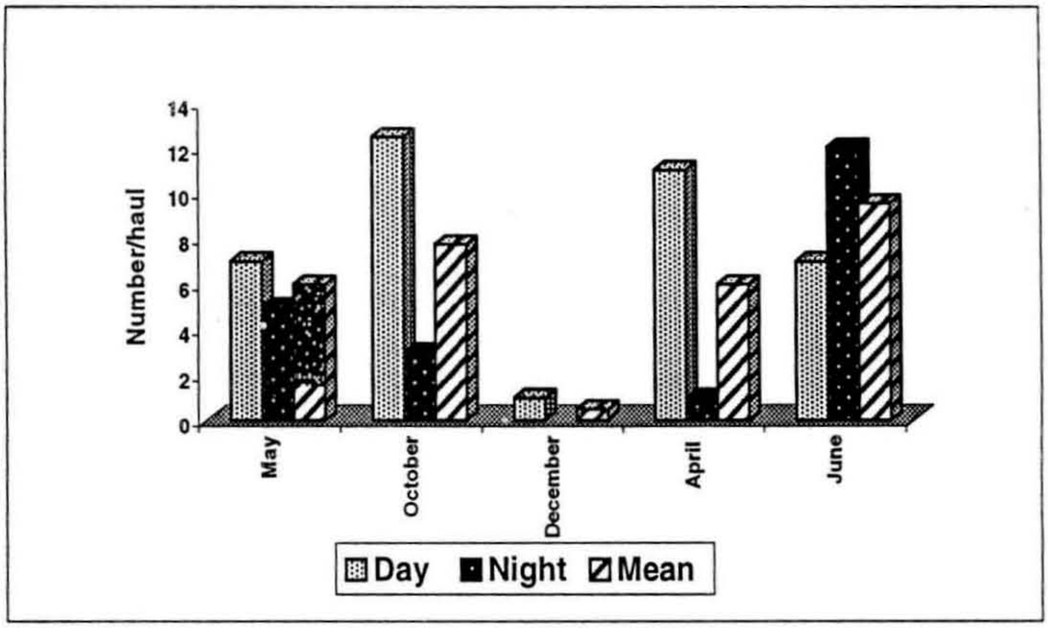


Figure 2.25 Monthly distribution of family Sternoptychidae

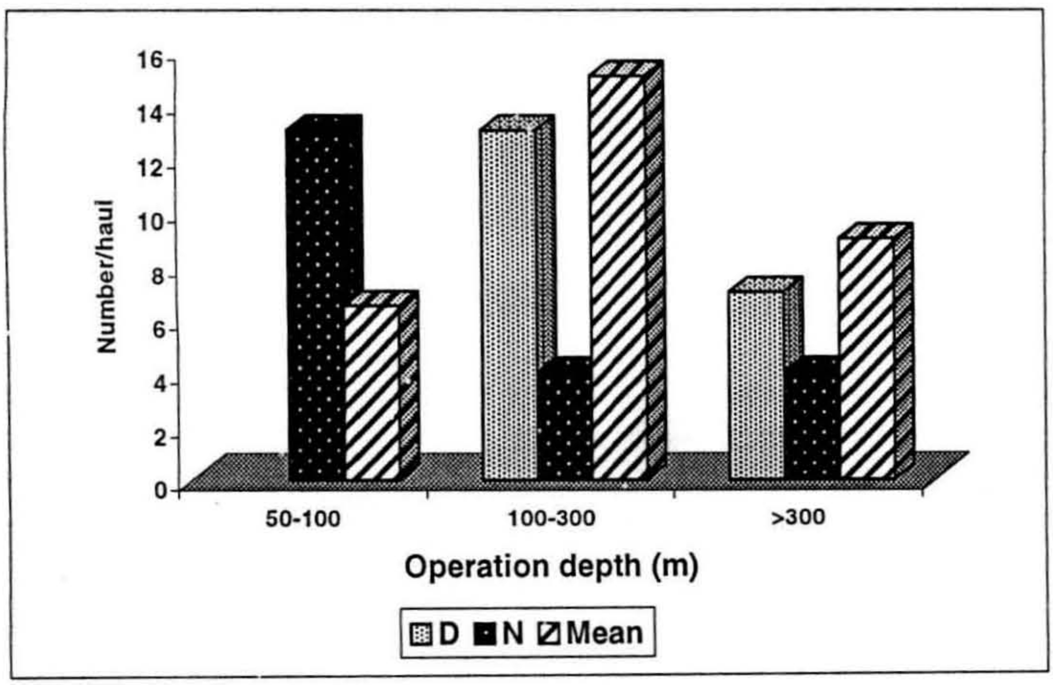


Figure 2.26 Vertical distribution of family Sternoptychidae

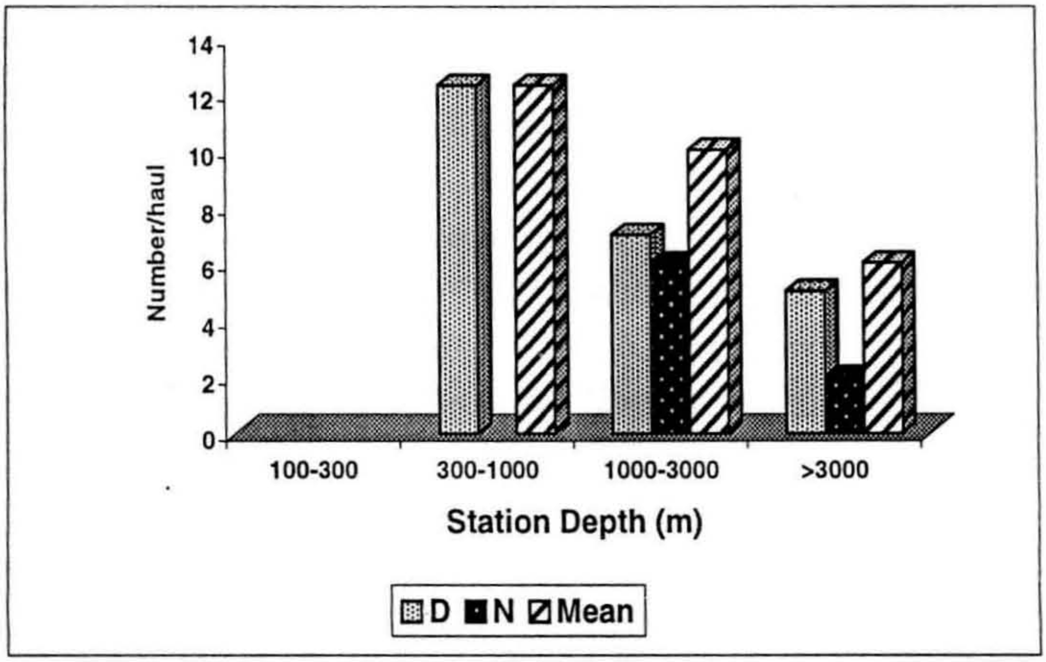


Figure 2.27 Horizontal distribution of family Sternoptychidae

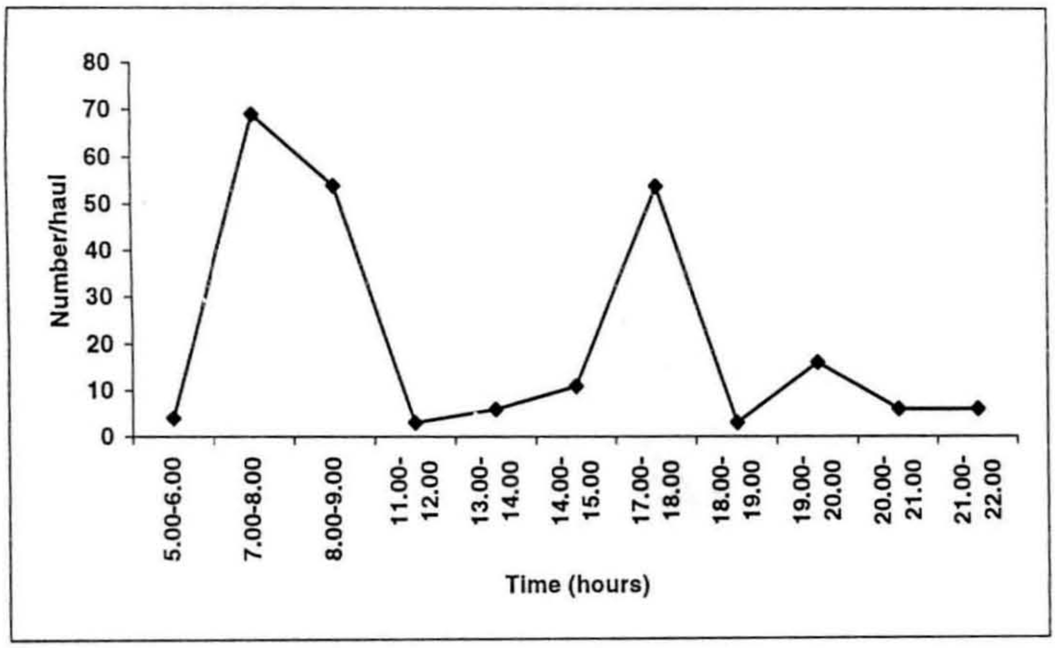


Figure 2.28 Temporal distribution of family Sternoptychidae

2.3.5.7 Genus *Argyropelecus*

The genus Argyropelecus consisted of 3 species i.e., *A. sladeni, A hemigymnus* and *A. affinis*.

2.3.5.7a *Argyropelecus sladeni*

The high occurrence of this species of family Sternoptychidae was recorded during day at Lat. 9°30'N and Long. 75°01'E. with a occurrence of 47 numbers . The operation depth was 150m and station depth was 958m , in the month of October. The details of the catch ,station position ,depth , operational depth, time is shown in Table 2.24.

Table 2.24: Distribution of *A. sladeni.*

Month	Time	Lat	Long	Stn. Depth (m)	Opn. Depth (m)	No.
October	8.00-8.30	9°30'	75°01'	958	150	47
May	20.00-20.30	9°59'	72°01'	2403	210	6
October	21.00-21.30	6°38'	77°31'	2415	390-400	4
May	11.15-11.40	12°54'	68°04'	4186	400	3
May	19.40-20.10	9°59'	69°54'	4530	180	2
June	7.10-7.40	11°03'	75°01'	620	270	2
October	5.00-5.30	10°31'	68°32'	4452	120	2
October	16.00-16.30	6°09'	76°31'	2136	400	2
May	14310-14.40	7°59'	75°03'	2762	380-400	1

2.3.5.7b *Argyropelecus hemigymnus*

The occurrence of *A. hemigymnus* was the highest at 7°59' and 75°03'. The other details such as the depth ,latitude ,longitude , month of occurrence is shown in the Table.2.25

Table 2.25. Distribution of *A. hemigymnus*.

Month	Time	Lat	Long	Stn. Depth (m)	Opn. Depth (m)	No.
May	14.10-14.40	7°59'	75°03'	2761	380-400	9
October	7.45-8.15	10°00'	7300'	1980	350	3
June	7.50-8.20	12°02'	74°19'	531	320	2
October	13.10-13.40	7°59'	74°02'	2768	400	2

2.3.5.7c *Argyropelecus. Affinis*

The occurrence of *A. affinis* was the highest at 10°00' and 73°00' during day at vertical depth of 350 m and station depth of 1980m.(Table 2.26).

Table 2.26. Distribution of *A.affinis*.

Month	Time (Hrs.)	Lat	Long	Stn. Depth (m)	Opn. Depth (m)	No.
October	7.45-8.15	10°00'	73°00'	1980	350	26
October	17.30-18.00	10°00'	71°80'	3646	280	13
June	19.40-20.10	13°01'	73°37'	1048	75	12
December	8.25-8.55	13°01'	70°57'	2405	320	5
October	13.10-13.40	7°59'	74°02'	2768	400	2
October	13.30-14.00	14°31'	71°32'	3991	750	1

2.3.5.8 d. *Polyipnus indicus*

The highest number of *P.indicus* was recorded ain the south west coast during day at greater depths of 330m (operation depth) and station depth 573m. (Table 2.27)

Table 2.27: Occurrence and distribution of *P. indicus* .

Month	Time (Hrs.)	Lat	Long	Stn. Depth (m)	Opn. Depth (m)	No.
April	17.45-18.10	10°00'	75°32'	573	330	32
April	7.10-7.40	12°34'	74°06'	792	300	17
April	7.25-7.55	9°04'	75°45'	345	260	7
April	17.40-18.10	9°12'	75°44'	532	310	6
June	17.10-17.40	11°49'	74°26'	382	280	3
April	18.40-19.10	13°09'	73°40'	531	370	3
April	14.50-15.20	10°19'	75°28'	1120	350	2

2.3.6 Biomass estimation

The biomass in tonnes ranged from 0.49 tonnes to 1820 tonnes. The biomass in tonnes (1°square) is shown in Table 2.28.The highest biomass of 1051 tonnes was recorded during day at station depth 3646m and operation depth 280m. At night a high biomass of 133 tonnes was recorded. The day and night biomass recorded is shown in Table 2.29 and 2.30 respectively.

The spatial biomass was high at 13° (1228 tonnes) during day and at night high biomass was recorded at 6° (133 tonnes) as shown in Figure 2.29. The vertical biomass during day and night was high at depths greater than 300m (286 tonnes and 133 tonnes respectively) (Figure 2.30) The monthly biomass in tonnes showed a high occurrence in October. (Figure 2.31)

2.4 Discussion

The results of this study have given a preliminary knowledge of the horizontal, spatial , seasonal , temporal and depth wise distribution During this period of study the thickness of the DSL varied from 20-400m. In the Indian EEZ, in the present study the family Photichthyidae represented by two genus i.e., *Vinciguerria* and *Icthyococcus* and three species *Vinciguerria nimbaria*, *Vinciguerria lucetia* and

Table 2.28 Estimated Biomass of family Sternoptychidae

Sl.No.	Month	Time	D/N	Lat	Long	Stn. depth (m)	Opn. depth (m)	Tonnes (t)
1	April	17.45-18.15	D	10°00'	75°32'	573	330	212.76
2	April	7.10-7.40	D	12°34'	74°06'	792	300	173.18
3	April	17.40-18.10	D	9°12'	75°44'	532	310	173.18
4	April	7.25-7.55	D	9°04'	75°45'	345	260	155.8
5	April	14.50-15.20	D	10°19'	75°28'	1120	350	49.48
6	April	7.10-7.40	D	12°29'	74°09'	431	300	29.69
7	April	18.40-19.15	D	13°09'	73°40'	531	370	9.9
8	April	21.00-21.30	N	10°16'	75°29'	1089	50	7.42
9	Dec	8.25-8.55	D	13°00	70°57'	2405	320	259.77
10	Dec	13.45-14.15	D	13°01'	72°57'	1937	340	43.3
11	June	19.40-20.10	N	13°01'	73°37'	1048	75	111.33
12	June	17.10-17.40	D	11°49'	74°26'	382	280	29.68
13	June	7.10-7.40	D	11°03'	75°01'	620	270	14.84
14	June	7.50-8.20	D	12°02'	74°19'	531	320	9.9
15	May	14.10-14.40	D	7°59'	75°03'	2761	380-400	81.64
16	May	14.10-14.40	D	7°59'	75°03'	2762	380-400	81.64
17	May	11.15-11.45	D	12°54'	68°04'	4186	400	20.41
18	May	20.00-20.30	N	9°59'	72°01'	2403	210	17.32
19	May	19.40-20.10	N	9°59'	69°54'	4530	180	2.48
21	May	19.40-20.10	N	9°59'	69°54'	4530	180	2.48
22	October	7.45-8.15	D	10°00'	73°00'	1980	350	1820.86
23	October	7.45-8.16	D	10°00'	73°00'	1980	350	1820.86
24	October	17.30-18.00	D	10°00'	71°80'	3646	280	1051.45
25	October	16.00-16.30	D	6°09'	76°31'	2415	400	134
26	October	21.00-21.30	N	6°38'	77°31'	2415	390-400	133.6
27	October	13.10-13.40	D	7°59'	74°02'	2768	400	74.22
28	October	13.10-13.40	D	7°59'	74°02'	2768	400	74.22
29	October	5.00-5.30	N	10°31'	68°32'	4452	120	2.47
30	October	13.30-14.00	D	14°31'	17°32'	3991	750	0.49
31	October	13.30-14.50	D	14°31'	70°32'	3991	750	0.49

Table 2.29 Estimated Biomass of family Sternoptychidae (Day)

Sl.No.	Month	Time	Lat.	Long.	Stn. depth (m)	Opn. depth (m)	Tonnes (t)
1	October	13.30-14.50	14°31'	70°32'	3991	750	0.49
2	May	14.10-14.40	7°59'	75°03'	2761	400	122.46
4	October	13.10-13.40	7°59'	74°02'	2768	400	111.33
6	October	16.00-16.30	6°09'	76°31'	2415	400	134
7	May	11.15-11.45	12°54'	68°04'	4186	400	20.41
8	April	18.40-19.15	13°09'	73°40'	531	370	9.9
9	April	14.50-15.20	10°19'	75°28'	1120	350	49.48
10	October	7.45-8.15	10°00'	73°00'	1980	350	2731.29
12	Dec	13.45-14.15	13°01'	72°57'	1937	340	43.3
13	April	17.45-18.15	10°00'	75°32'	573	330	212.76
14	Dec	8.25-8.55	13°00	70°57'	2405	320	259.77
15	June	7.50-8.20	12°02'	74°19'	531	320	9.9
16	April	17.40-18.10	9°12'	75°44'	532	310	259.77
18	April	7.10-7.40	12°29'	74°09'	431	300	29.69
19	June	17.10-17.40	11°49'	74°26'	382	280	29.68
20	October	17.30-18.00	10°00'	71°80'	3646	280	1051.45
21	June	7.10-7.40	11°03'	75°01'	620	270	14.84
22	April	7.25-7.55	9°04'	75°45'	345	260	155.8

Table 2.30 Estimated Biomass of family Sternoptychidae (Night)

Sl.No.	Month	Time	Lat	Long	Stn. depth (m)	Opn. depth (m)	Tonnes (t)
1	May	20.00-20.30	9°59'	72°01'	2403	210	17.32
2	May	19.40-20.10	9°59'	69°54'	4530	180	2.48
4	October	21.00-21.30	6°38'	77°31'	2415	390-400	133.6
5	June	19.40-20.10	13°01'	73°37'	1048	75	111.33
6	October	5.00-5.30	10°31'	68°32'	4452	120	2.47
7	April	21.00-21.30	10°16'	75°29'	1089	50	7.42

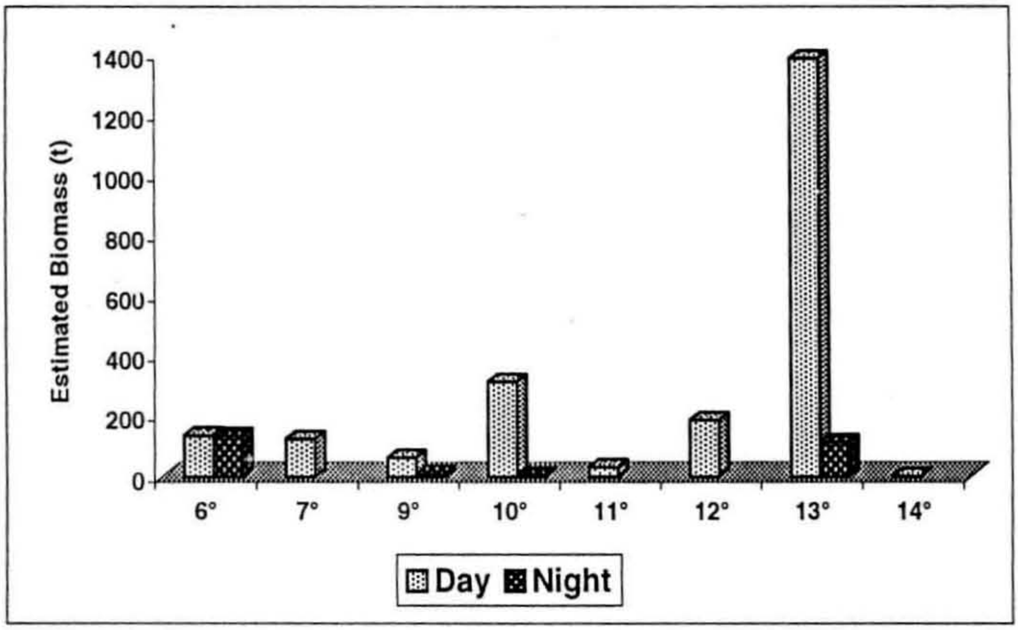


Figure 2.29 Estimated Spatial Biomass of Family Sternoptychidae

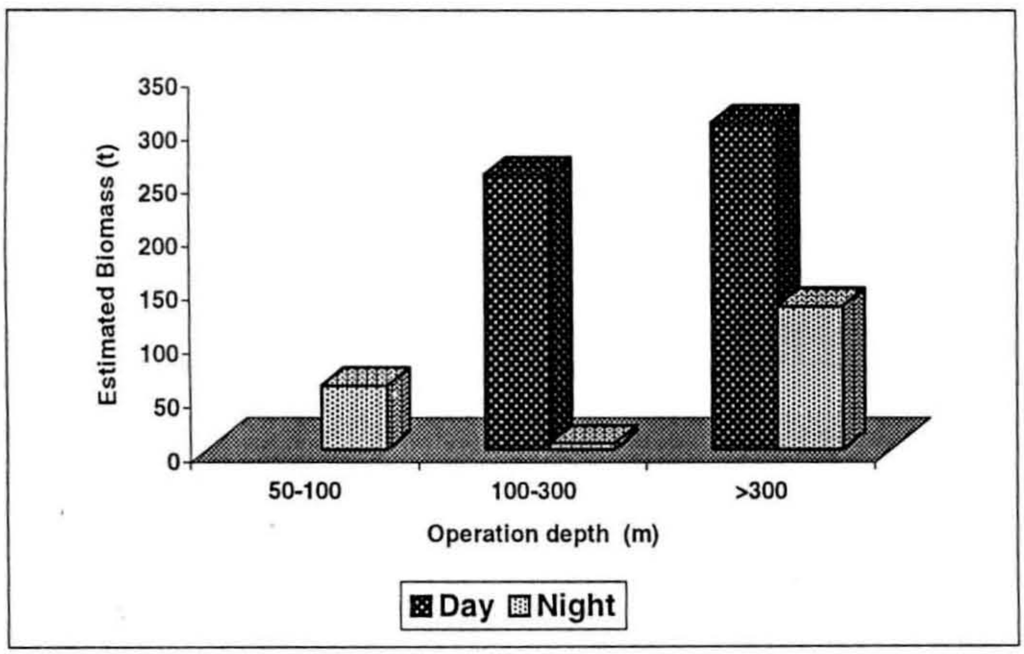


Figure 2.30 Estimated Vertical Biomass of Family Sternoptychidae

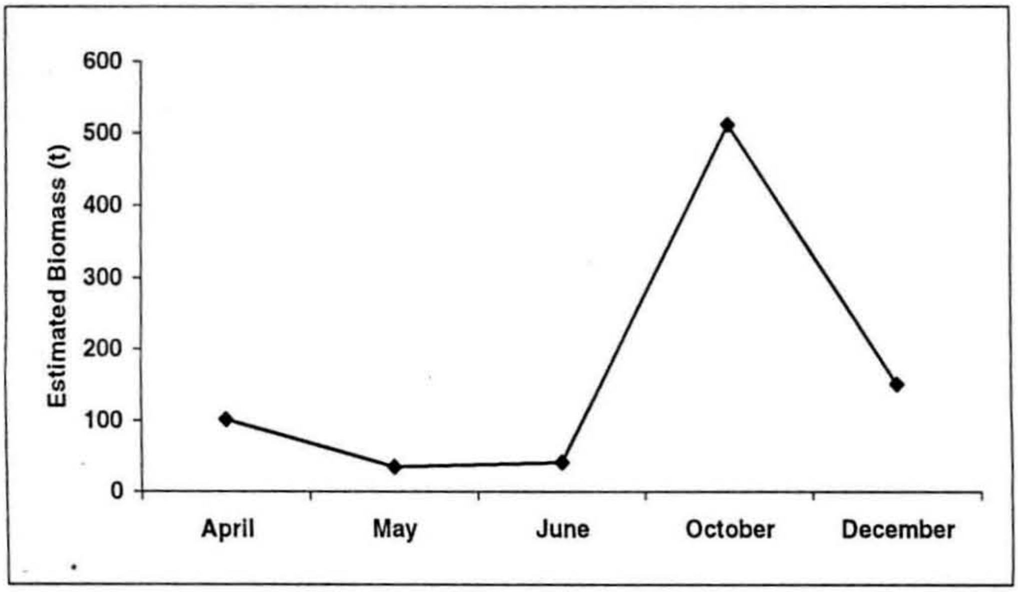


Figure 2.31 Estimated Monthly Biomass of Family Sternoptychidae

Ichthyococcus ovatus were encountered. The highest biomass of 1954 tonnes was recorded for the genus *Vinciguerria* and the highest biomass of 1820 tonnes was recorded for family Sternoptychidae. Silas and George 1969 have reported a large occurrence of *V. nimbaria* from the Arabian Sea. Menon *et al.*, 1996 reported 95% of *V. nimbaria* in the Arabian sea, while *V. attanuata* and *V. poweriae* were only present at 5%. *I. ovatus* was not reported. Rhyther *et al.*, 1966 reported *V.nimbaria*, *V. attenuata* , *V. poweriae* and *Ichtyococcus ovatus* . *Vinciguerria nimbaria* dominated the catches. Backus *et al.*,1970 showed that *I. ovatus* and *V. nimbaria* are tropical. *V.attenuata* was considered to be a synonym to *V. lucetia* (Weitzman ,1986) The absence of *V. poweriae* in the present study could be due to their further reduction in the Arabian sea. A high percentage of *Vinciguerria nimbaria* in the Indian ocean has been reported by Gorbunova, 1990 and Kalnina and Shevchenko (1984). Zelck (1993) reported the presence of *Vinciguerria nimbaria* in the south Atlantic. Gordina (1987) has reported abundance of *V. nimbaria* from North and Central East Atlantic from depths ranging from 250-820m.

Vinciguerria lucetia has been recorded by Brauer, 1906 (New Amsterdam) off Sumatra; Bay of Bengal, from between Ceylon and Chagos Archipelago and off Zanzibar. Weber 1913 recorded *Vinciguerria lucetia* from Molucco passage (Indonesian waters) .The presence of *Vinciguerria lucetia* have also been reported by Johnson and Feltes (1984), Gorbunova (1977), Silas and George (1969) and Ahlstrom and Counts (1958). Harold and Clarke (1990) have recorded *Ichthyococcus ovatus*.

The biomass of *Vinciguerria nimbaria* was found to be high when compared to that of *V. lucetia* . *Ichtyococcus ovatus* was reported at only 3 stations in single numbers.

Spatial distribution studies have shown that that high latitudes above 15°N showed a higher concentration of the family Photichthyidae. This is in agreement with studies done by Gorbunova, (1977) showing a high abundance of *V. nimbaria* in all areas of the Indian Ocean North of 20°S except for shelf region.

Studies on the bathymetric distribution showed that the fishes belonging to the family Photichthyidae showed extensive vertical migrations on a daily basis. These migrations may extend well into the epipelagic region where the fish do most of the feeding and even to the surface at night (Haedrich,1996) .The fishes *V. nimbaria* and *V. lucetia* along with other mesopelagic fishes of the DSL were seen at depths of 600-1000m during day and 50-200m depth during night. A percentage was seen at the surface even during day in confirmation with earlier studies made by Menon *et al.*, 1996 and Roger and Marchal, 1994. These fishes have been found as prey in Yellow fin (*Thunnus albacares*) and Skipjack tuna (*Katsuwonus pelamis*) which do their feeding mostly diuring day. Menon opined that during daylight the DSL descends far down to 400-500m or more. They occupy different depths below the predator species habitat.

Gorbunova, 1977 has reported on the diurnal migrations of *V. lucetia*. He opined that as the thickness of the upper mixed layers with temperatures above 20°C increases the layers inhabited by the larvae of *V. lucetia* gradually shifts to greater depths. The larvae of the fish species perform diel vertical migration rising at night nearer to the surface.

The diurnal vertical migrations is in confirmation with earlier studies made by Ropke, 1993;Haedrich and Merett, 1992; Kalnina, 1986. The widespread occurrence of dial vertical migration among fishes suggests that there are adaptive advantages associated with the behaviour. This is mainly to enhance feeding (Neilson and Perry, 1990); avoidance of predators (Hunter and Sanchez, 1976; Yamashuta *et al.,* 1985), metabolic advantages. (Wurtsbaugh and Nevermann, 1988), Transport (Fortier and Leggett, 1983) and retention (Sinclair, 1988).

The night time abundance was found to be higher than day time abundance. (Ropke 1993). Workers like Aron (1962), King and Iverson (1962), Percy and Laurs (1966) attributed this diurnal differential abundance as due to visual avoidance of the gear , differential speed of ascent and descent in night and day respectively, the former being slower than the latter and also better escapement and scatter during the day.

The seasonal distribution studies indicate higher abundance of Vinciguerria in October- December which agrees with earlier findings by Silas and George (1969) and Fursa (1976). They found that the fishes of the family Photichthyidae occur more in the Oceanic than in the neritic waters with high abundance during post monsoon and premonsoon months. The finding is consistent with that of George (1989) based on Icthyoplankton surveys in the south west coast of India.

Temporal distribution studies have shown that the fishes belonging to the genus *Vinciguerria* start their ascent to the surface at around 19.00hrs and are even seen at the surface . They begin their descent to the deeper areas to around 500m depths from early morning 6.00hrs. The night time abundance was more in the present study. The hypothesis by Marchal and Lebourges (1996) is as follows ' During night the aggregations of this species were observed in or just below the thermocline. At dusk schools at the thermocline disperse for a while but quickly rebuild new aggregations. Temporal variation is clearly seen before 19:00 local time, the daytime situation prevails with small dense schools. Theres a rapid change between 19:00-19:15 hrs. During this short period the packing density falls then increases continuously for 45 minutes. At the end of the night, fish are in a more or less continuous thin layer at 80m depth. At the first light of dawn they begin to rise upwards. With daylight scattered detections appear very close to the surface and very soon congregate in dense schools'. The present study doesn't confirm with the above hypothesis due to higher abundance during night when compared to day. In the cruises on board **FORV** ***Sagar Sampada*** it has been observed on the echosounder that the DSL gets scattered to greater depths with day light. However a part of the DSL comprising of the mesopelagic fishes continues to stay within the predator species habitat.

The abundance of Family Photichthyidae in the Arabian sea can be correlated to the biomass of zooplankton in premonsoon ,monsoon and postmonsoon and the average temperature, salinity in the water. (Wang *et al.*,1993)

In contrast to family Photichthyidae family Sternoptychidae are seen to undergo little or no diurnal migrations. They are seen at greater depths both during day and night.

The family sternoptychidae are deep sea pelagic fishes found in deeper waters from 500-800m depths. Adults are mesopelagic fishes are seen below 200m depth and rarely seen in surface waters. They are common in all the Oceans including the Mediterranean Sea. In the folowing study based on cruise samples from May 1998-June 2002, the species *Argyropelecus sladeni, Argyropelecus hemigymnus, Argyropelecus affinis and Polyipnus indicus* of the family Sternoptychidae were encountered.

A.affinis was seen to be between depth of 300m to 650m. They do not exhibit extensive diurnal vertical migrations. Out of 7 stations in which they were recorded they occurred at depth greater than 250m. The confirms with earlier literature (Weitzman ,1986), that they undergo very little vertical migration.

A.hemigymnus is also seen to exhibit very little vertical migration. Only day samples were available as operation during night was not conducted at deeper layers. Found to be concentrated at 250-650m operation depth both in the south west and north west coast of India.

A.sladeni was found not to exhibit vertical migrations. At night a minimum yield of 12 numbers was reported at depths of 180-400m. During day a larger number were caught at depths of 200-400m with a yield of 57 numbers. The highest number of 47 number/haul during day was observed in the south west region at lesser depth of 150m. Since they were recorded at 200-400m both during day and night they may undergo very small vertical migration . (Weitzman ,1986)

Polyipnus Indicus has been reported by Schultz ,1961. They were seen above 200 m by day. Do not exhibit diurnal migrations.

Thus the present study on the distribution of the family Photichthyidae and family Sternoptychidae in the west coast of India have clearly shown that the the species of the family Photichthyidae show extensive diurnal migrations seen at depths of 600-1000m during day and 50-200m during night while the fishes of the family Sternoptychidae show very little or no diurnal migrations seen at depths of 500-800m both during day and night. *V. nimbaria* (Photichthyidae) is more abundant in the Arabian sea when compared to *V. lucetia* (Photichthyidae) and *I.ovatus* (Photichthyidae). The species of the family Photichthyidae are more abundant in the north west coast during the months of October-December. *V. nimbaria* and *V. lucetia* do not show much variation in their distribution and vertical migration. The species of the family Sternoptychidae differ in their depth wise distribution. They are more abundant during day in the south west coast.

Chapter - III

Taxanomy

3. TAXONOMY

3.1 Introduction

The family Photichthyidae, known as light fishes, contains 21 species belonging to eight genera. The Photophores on body are discrete, arranged in two or more longitudinal rows. They are found in all the major oceans and reported to inhabit vertical depths of 50-280m and horizontal depths of 200 to 4525m. The family Sternoptychidae, common name being hatchet fishes, consists of ten genera with a total of about 45 known species. They are elongate to deep-bodied bioluminescent fishes. The body is markedly deep. A peculiarly developed keel formed by the projecting upper neural processes, is present on the base in front of the dorsal fin. They are found in all the major oceans and reported to inhabit vertical depth of 75 to 750m and horizontal depths of 531 to 4452m. They are mesopelagic and bathypelagic fishes. Only a few species belonging to family Sternoptychidae undergo vertical migrations. Most of the fishes belonging to this family are non-migratory. The fishes of both these families attain less than 10cm.

3.2 Materials and Methods

The samples needed for identification were obtained from the cruises of the **FORV *Sagar Sampada*** during 1998-2000. The samples were collected using Isaac Kid Midwater trawl (IKMT) operated for 30 minutes duration at varying depths.

The specimens are preserved onboard the vessel in 10% formalin and brought to the laboratory for taxonomical work. The fishes were studied in detail about the photophores and their morphometric characters such as total length, standard length and eye shape.

Arrangement of photophores: The terminology followed for the photophores in the family Photichthyidae was that of Ahlstrom and Counts (1958).

The Key to families was done by following the key in Smith (1986)

1.BR photophores 11-12,AC photophores,12-16,not clumped
never with a chin barbell . . . . **Photichthyidae.**

2.BR photophores 6. AC photophores series with 2
or more photophores clumped into specialized light
organs surrounded by black or silvery
pigment. . . . . **Sternoptychidae.**

3.3.1.1 FAMILY PHOTICHTHYIDAE (Schaefer *et al.*, 1986)

Head and body compressed, bioluminescent fishes of mesopelagic and bathypelagic habitat. General body shape similar to the gonostomatids. Serial photophores with a lumen and a duct.; gill rakers well developed in young and adults; usually two supramaillaries; adipose fin present; Found in all the major oceans. Consist of eight genera with a total of about 21 species. Represented in the Arabian Sea with two genera and 3 species.

Photophore nomenclature definition for the fishes of the family Photichthyidae following Ahlstrom *et al.*, 1958 is shown in Table 3.1.and a digrammatic representation of the arrangement of Photophores is shown in Figure 3.1.

Table 3.1: Photophore nomenclature definition and codes for the family Photichthyidae following Ahlstrom *et al.*, 1958.

Code	Description
SO	Photophores situated at anterior end of lower jaw.
IS	Photophores on the Isthmus
ORB	Photophores in eye region
OP	Gill cover
BR	Lower jaw
OV	Lateral photophores between Pectoral and Pelvic fin.
Lateral VA	Lateral photophores between Pelvic and Anal fin
AC	Anal and caudal fin.
IV	Ventral photophores between pectoral and pelvic
Ventral VA	Ventral photophores between Pelvic and Anal fin
IC	All photophores from isthmus to caudal region

Remarks:

The family Photichthyidae was placed under family Gonostomatidae previously but has been revised and placed as a separate family (Schaefer *et al.*, 1986).The Spelling family 'Photichthyidae' is spelt also as Phosichthyidae. Eschmeyer 1990:312 gives reasons for accepting the names Phosichthyidae and Phosichthys. Based on popular acceptance of the family name Photichthyidae (Evseenko and Suntsov, 1995;Aguilar Ibarra and Vicencio Aguilar, 1994; Nelson 1994;Roepke, 1993;Rodriguez *et al.* 1993; Kashkin, 1993; Sieg, 1989,1992; Mozgovoy and Bekker, 1991;Rees et al., 1990; Post, 1985; Ahlstrom *et al.*, 1984; Johnson and Feltes, 1984; Borodulina, 1984; Krefft, 1983; Marchal and Lebourges,

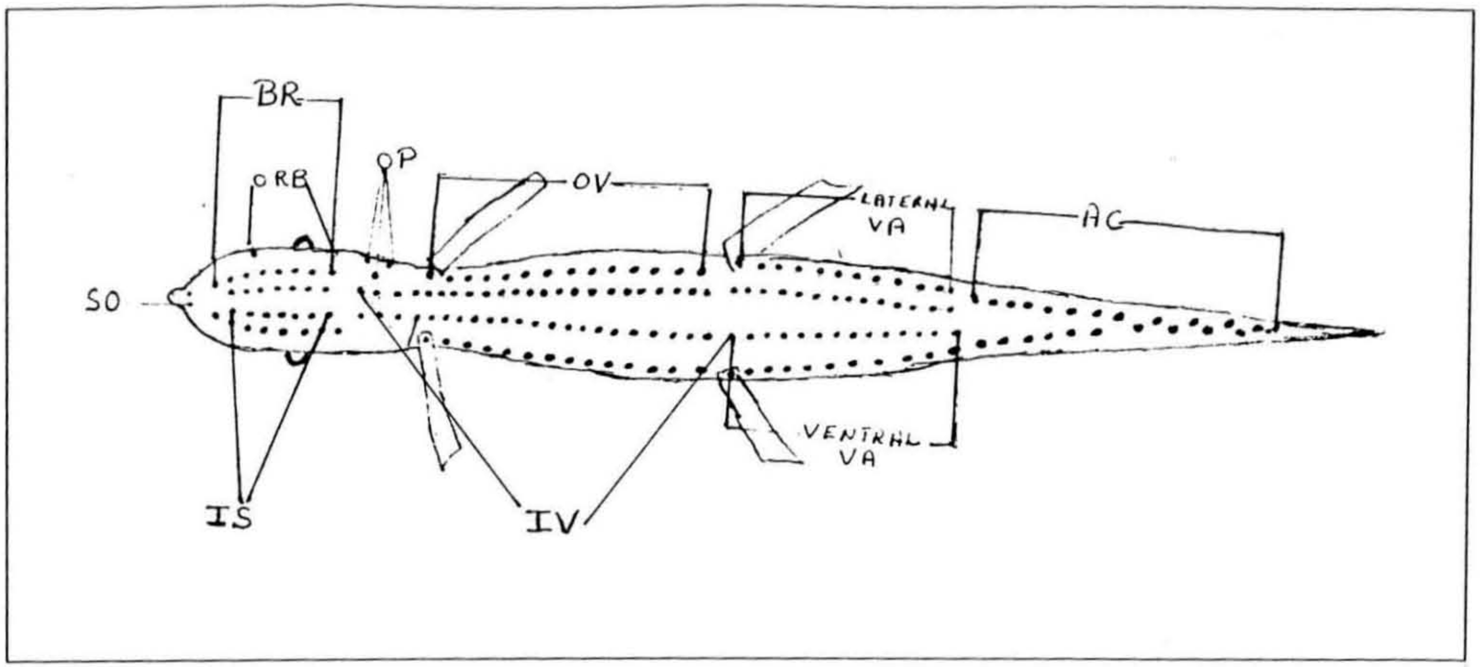


Figure-3.1: DIAGRAMMATIC REPRESENTATION OF PHOTOPHORES IN THE GENUS *VINCIGUERRIA*.

1995; Goran and Pagano 1999) in the present work Photichthyidae was used instead of Phosichthyidae (Eschmeyer 1990; Watson ,1996).

Key to genera

1. Body shorter and deeper , anal short to moderate, AC photophores 12-16--- -----------------------*Vinciguerria*

2.Vorigin behind D origin; BR photophores 11-12; jaws short, adipose fin long, -----------------------*Icthyococcus.*

3.3.1 Genus *Vinciguerria*

Synonyms :

Poweriae ,	Bonoparte (1840), *Icon.Fauna Ital.*,3(27), Pesci, punt. 138 (type: *Gonostomus poweriae* Cocco, 1838, 'Messina'). Invalid synonym
Zalarges	Jordan and Williams in Jordan and Starks, (1896). *Proc.Calif Acad.Sci.*, 1895 (1896), [2]5:793 (type: *Zalarges nimbarius* Jordanand Williams 1896, 'Pacific'). Invalid synonym
Narooma	Whitely ,1935, *Rec.Aus.Mus.*, 19(4):215 (type:*Narooma benefica* Whitely. 1935) .Invalid synonym
Vinciguerria	Jordan and Everman 1896, p 513; Johnson and Feltes 1984; Ahlstrom *et al.*, 1984:185; Schaefer *et al.*, 1986 :245. Valid Synonym.

Diagonostic Characters :

Body elongate, compressed. Scales thin ,cycloid with uninterrupted series of lateral photophores. Eyes large. Gape of mouth wide. Teeth on both jaws , palatine pterygoid and vomer. Gill openings wide. Gill rakers well developed. Dorsal fin with

14 rays. Origin midway from snout to base of caudal and in advance of anal origin. Pelvic origin in advance of dorsal origin. Anal with 14-15 rays. Adipose fin short. Caudal equally forked. Eyes round or slightly tubular. Photophores conspicuous. The photophores have been grouped into the head photophores and the body photophores.

The head photophore counts are similar for both the species of the Genus *Vinciguerria* i.e., *V. nimbaria* and *V. lucetia* and are grouped into:

1. Symphysal (SO): One pair on underside of lower jaw.
2. Orbital (ORB): 2 per side
3. Opercular (OP): 3 per side ie., 1 behind centre of eye, 2 about in level with lateral row of photophores.
4. Branchiostegal photophores : 8 per side.
5. Isthimian photophores :7 per side along isthmus.

The body photophore counts ie., the lateral body photophores (OV and lateral VA) ; Ventral body photophores (IV and ventral VA) and Anal to caudal photophores (AC) differ for the species of the Genus *Vinciguerria.*

Distribution

Distributed in the Atlantic, Arabian sea, Bay of Bengal and Indo Pacific. Occur in high numbers in the west coast and east coast of India.

Key to species:

1. SO present; Ventral IV=21-23;Lateral OV photophores 13-14 and ventral VA=10-11. . . . . ***V. nimbaria.***

2. SO present ;Ventral IV=20-22;Lateral OV photophores 10-11 and ventral VA=9-10. . . . . ***V. lucetia.***

3.3.1.1 *Vinciguerria nimbaria*

Figure 3.2.

Zalarges nimbarius	Jordan and Williams, 1896 in Jordan and Starks, *Proc. Calif.Acad. Sci*:1895 (1896)(2) 5: 793 plate 76.
Vinciguerria nimbaria.	Ahlstrom and Counts, 1958:399- 405, figure 28-29; Grey, 1964: 130 figure 29-32.. Hulley, 1972, 205; Johnson and Barnett, 1975,288 ;Johnson and Feltes, 1984. Valid synonym
Vinciguerria sanzoi	Jesperson and Taning (1919); *Vidensk. Meddr dansk naturh. Foren., Kbh.*, 70:218, pl 17 (fig 2,5). Invalid synonym.
Gonostoma raoulensis ,	Waite (1910).

Number of species studied : 684

Diagnostic Characteristics:

Dorsal soft rays 13-15; Anal soft rays 12-14; Pectoral rays 9-11; Ventral fin 7; Gill rakers 17-26.

Head photophores: Symphysal (SO) One pair on underside of lower jaw; Orbital (ORB): 2 per side; Opercular (OP): 3 per side; Branchiostegal photophores : 8 per side; ĭsthimian photophores :7 per side along isthmus.

Body Photophores: Lateral photophores (OV: 13-14; lateral VA: 8-9) Ventral Photophores (IV:21-23 ;Ventral VA:10-11); AC photophores :13-13. Occassionally a sigle photophore (not paired) may be present in the group between the origin of the anal fin and the base of the caudal fin . Such a photophore is also included in the counts.

Eyes normal , Dorsum dark, flanks silvery, dark pigment streak associated with SO, premaxilla pigmented patch at anterior most IV photophore, both upper

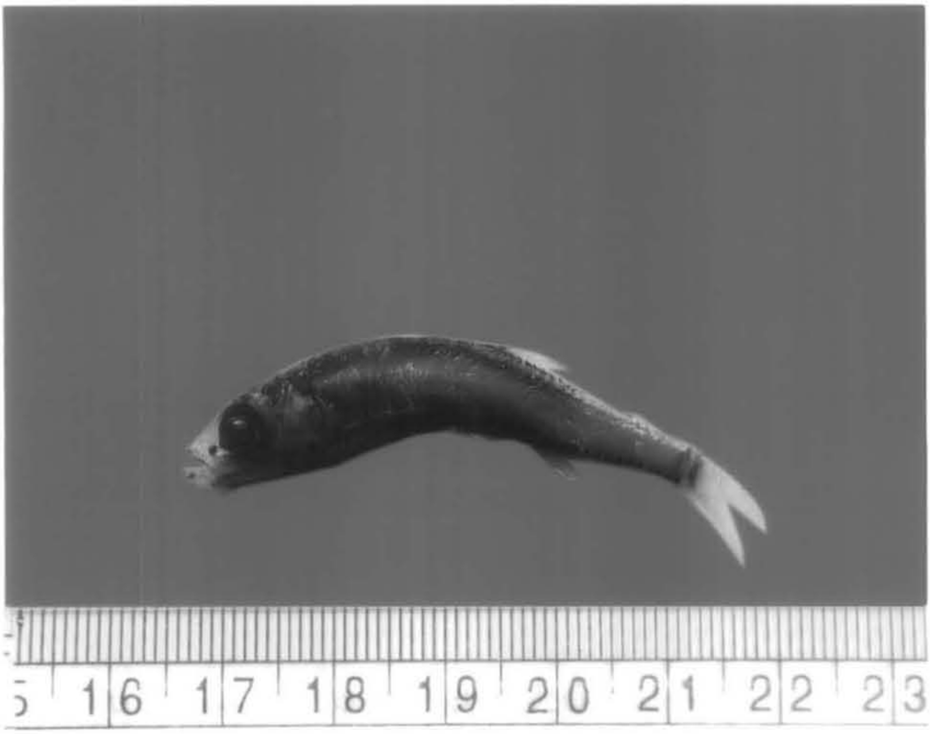


Figure 3.2 *Vinciguerria nimbaria* (Jordan & Williams, 1896)

Pectoral and outer Caudal speckled; caudal melanophores in ventral position in juveniles. Attains maximum length of 52.5mm. The upper part of the body and head are dusky. The abdomen especially between the two rows of photophores is dusky upto the vent. Similar pigment spots are present above the base of the caudal fin. The scales are deciduous and scale pockets are discernible on account of the fine rows of pigment spots.

Distribution and habitat: Mesopelagic 50-200m depth in night and 250-500m depth by day. Atlantic, 42°N to 23°S, Caribbean Sea; Indian Ocean, Arabian Sea, Red sea; East London to delagoa Bay. Adults stay mainly in 200-400m by day migrates to upper 100m by night. Tropical and subtropical waters of all 3 major oceans. Seen between 6°30'-20°00'N and 69°00'-73°00'E in the south and north west coast of India.

3.3.1.2 *Vinciguerria lucetia*

Figure 3.3

Synonyms

Maurolicus lucetius;	Garman, *Albatross Exp*. XXVI. *Fishes* 1899,pp242.
V. lucetia,	Brauer, *Deutsche Tiefsee-Exp. Tiefseefische*, 1906,pp97; Kottayar AN 1984; Eschmeyer, WN Editor 1999;Watson W.,1996.;Nelson, J.J . 1994.

Specimens collected: 162.

Diagnostic characteristics:

Dorsal soft rays 13-16 ;Anal soft rays 13-17; Pectoral 9-11; Gill rakers 39-43.

Head photophores: Symphysal (SO) One pair on underside of lower jaw; Orbital (ORB): 2 per side; Opercular (OP): 3 per side; Branchiostegal photophores : 8-9 per side; Isthimian photophores :7 per side along isthmus.

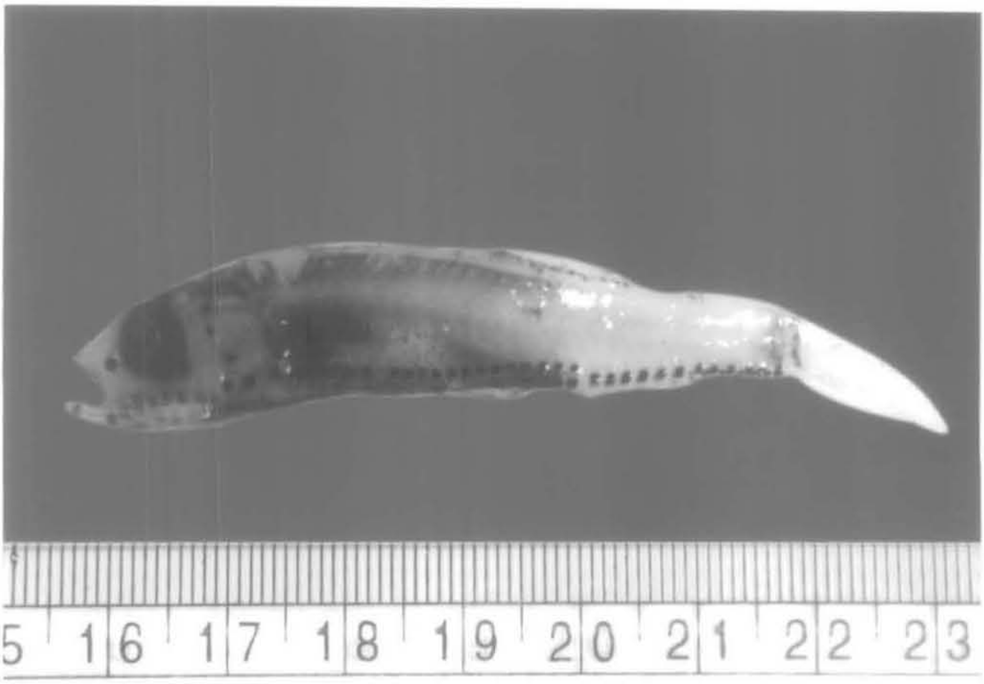


Figure 3.3 *Vinciguerria lucetia* (Garman, 1899)

Body Photophores: Lateral photophores (OV: 10-11; lateral VA: 8-8) Ventral Photophores (IV:20-23 ;Ventral VA:9-11); AC photophores :12-14.

Balckish above, sides of head and body silvery . A black spot at the end of the tail and some short black transverse stripes on back. Attains a maximum length of 50mm. Eye oval, equal to the pointed snout, twice as long as the slightly concave interorbital space. Gap of mouth wide. Upper jaw rounded posteriorly. Lower jaw with a prominent symphysal angle, its inferior posterior angle prominent enclosed between the maxillaries. Short adipose fin slightly behind the vertical through end of anal. Caudal long and deeply forked. In the jaws a series of small unequal teeth, slightly increasing in size backward.

Distribution:

Molucco passage (1500m); India to New Amsterdam, Pacific, West coast of Mexico and Central America, Atlantic, Gulf of Guinea.

Occurs in the west coast of India from Latitude 6°-21°N and Longitude 66°-75°E.

3.3.2 Genus *Icthyococcus*

Icthyococcus Bonoparte (1840) *Iconografia della fauna italica. Fascicles* 68 to 138, part 27, fase 138 Orthotype *I ovatus bon.*

Diagnostic characteristics:

Eye large, tubular directed oblique upwards, Teeth on jaws minute and uniserial. Vomer, palatines, pterygoids and tongue toothless. Photophores moderate to large. ORB-2 (Posterior ORB mid ventral to eye) OP3;BR 11-12;SO present or absent, no other photophores on head ; body with two rows ;AC photophores level;8th IV photophore elevated, OA level , ending at A origin, no other luminous tissue on head or body . Dorsal adipose fin long and low; small preanal ventral adipose fin present or absent. Anal fin base subequal to or slightly shorter than Dorsal base, its origin well behind that of Dorsal base. Ventral base behind Dorsal origin. Anus close to A origin.

Key to species:

2a. SO absent. . . . . *I. Ovatus*

2b SO present in fish greater than 17mm S.L. . . . . . . *.I polli*

3.3.2.1 *Icthyococcus ovatus*

Figure 3.4

Synonyms

Icthyococcus ovatus Brauer, 1906, pp94, Figure 39; Jespersen and Taning 1919; Grey 1964:155; Mukhacheva, 1980:4 . Valid synonym.

Gonostoma ovatus Cocco 1838: 169,PL 5,Figure 3 (Messina). Invalid synonym.

Total specimens :3.

Diagnostic characteristics

Body depth 32-36% SL. Photophores conspicuous closely set; On the head 2 orbital photophores, opercular (3); the inferior opercular (5); 11 branchiostegal photophores, 6-16 on the trunk along the ventral profile, 8 photophores on the isthmus, 17-24 thoracic, 10 ventral, 3 are rudimentary and are not evident, 7 photophores on the sides of the anal fin, 3 precaudal photopores laterally, 13 suprathracic photophores. Brown yellow, flanks silver, bases of fins and edges of scale pockets black. Attains maximum length of 55mm.

Distribution:

Subtropical waters of all oceans, Mediterranean Sea; likely to occur round SA; adults found mainly at 200-500m.

Occurrence in Lat. 6°N, 7°N, 8°N in the west coast of India.

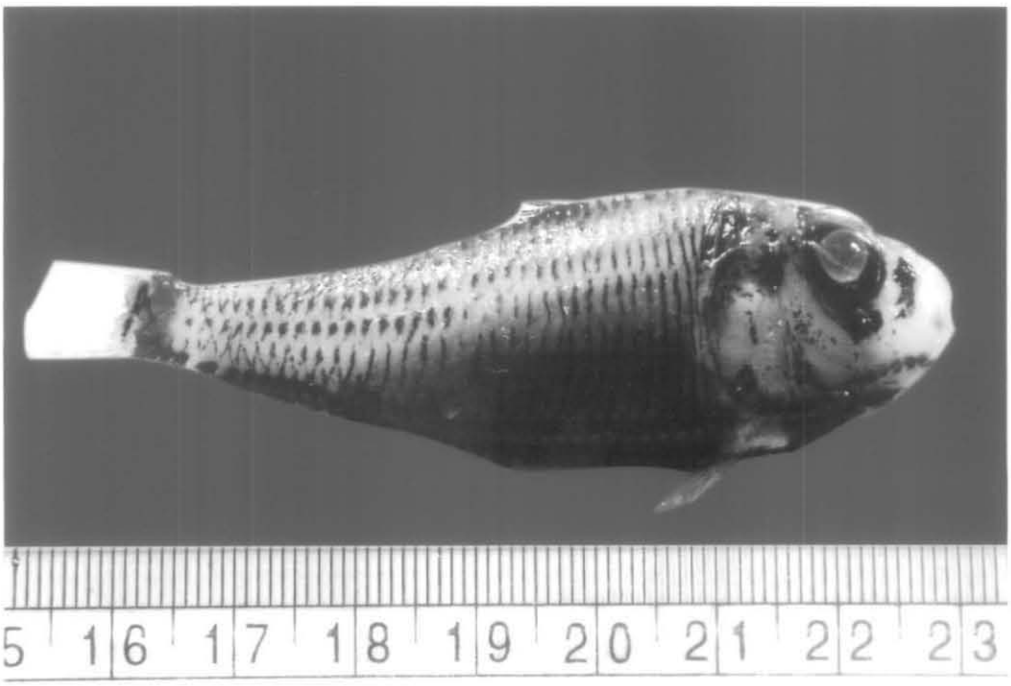


Figure 3.4 *Icthyococcus ovatus* (Cocco, 1838)

3.4. STERNOPTYCHIDAE (Weitzman ,1986)

This family comprises of 10 genera with a total of 45 species.Eight species of this family belonging to six genera are now known to inhabit the seas of India. They mostly all belong to the Nekton though they probably live below the depths to which day light penetrates.

Body naked or with very thin and deciduous scales. Barbels none. Margin of the upper jaw formed by the maxilla and premaxilla, both of which are toothed. Gill opening very wide, the opercular apparatus not always completely developed. Airbladder simple if present. Adipose fin present, but generally small. Series of phosphorescent bodies along the ventral aspect of the body.

Bioluminescent mesopelagic and bathypelagic fishes. Body deep and extremely compressed, pectoral fin low on body. Blade in front of the dorsal fin composed of specialized dorsal pterygophores, anal fin sometimes divided.

In the present study, in the west coast of India two genera i.e., *Argyropelecus* and *Polyipnus* and four species i.e., *Argyropelecus affinis, A. sladeni, A hemigymnus* and *Polyipnus indicus* were encountered.

Taxanomic position of the family Sternoptychidae:

Phylum	:	Chordata
Subphylum	:	Vertebrata
Class	:	Osteichthyes
Division	:	Teleostei
Superorder	:	Protacanthopterygii
Order	:	Stomiiformes
Family	:	Sternoptychidae.

The Photophore nomenclature was followed as given by Baird 1971.The Table 3.2 gives the code and the description. Figure 3.5 is a diagrammatic representation of the arrangement of photophores in the genus *Argyropelecus* and *Polyipnus*.

Table 3.2: Photophore nomenclature definition and codes for the deep bodied Sternoptychids as given by Baird 1971.

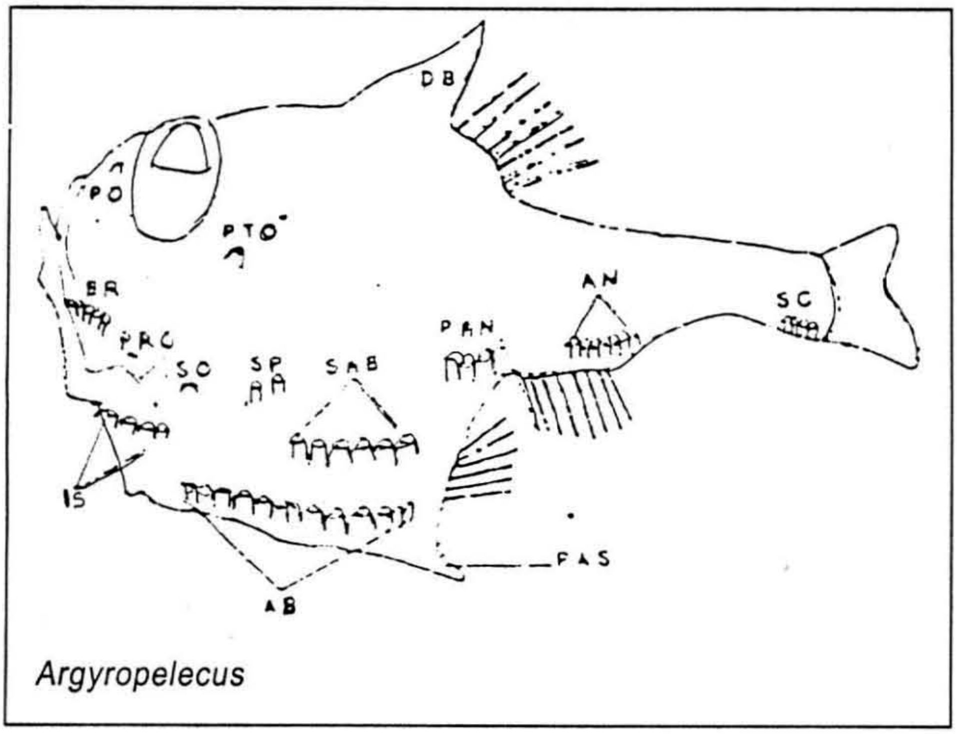
Bairds Code	Description
SO	Subopercle photophore
PO	Photophore located anterior to orbit
PTO	Photophore located posterior to orbit
BR	Photophores on the branchiostegal membranes
IS	Photophores on the Isthmus
AB	Photophore of Ventral series located between Pectoralfin base and Pelvic
PAN	Photophores found anterior to to anal fin
AN	Photophores found above anal fin
SC	Photophores on sub caudal peduncle
SAB	Photophores located above the the abdominal series.
SP	Photophores present above the pectoral fin
L	Photophores laterally above PAN found only in *Polyipnus* sp.
SAN	Supra anal photophores

Key to the Genera followed using the key in Smith (1986):

1 Dorsal fin preceded by a large triangular transparent plate (a curious transparent fold of skin supported by interhaemal rays); an abrupt ventral constriction, between trunk and tail. **3**

2 Dorsal fin preceded by a forked spine: no abrupt ventral constriction between trunk and tail. . . . .***Polyipnus***

3. Eye telescopic: anal divided :ventral constriction between trunk and tail without integumentary plate, body hatchet shape.. ***Argyropelecus***



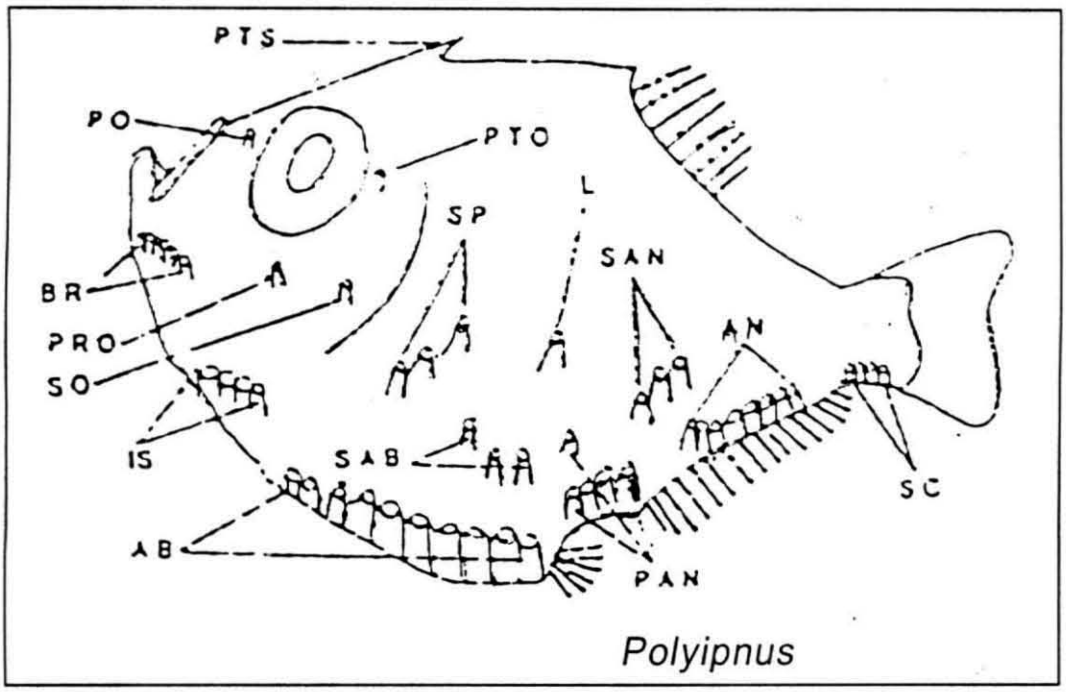


Figure-3.5: Diagrammatic Configuration Of Photophores & Other External Features Of the Hatchet Fish Genera *Argyropelecus* & *Polyipnus*

Source: Smith Sea Fishes p.255

3.4.1 Genus *Argyropelecus*

Synonym

Argyropelecus, Cocco Giorn. *Sci. Sicil.* 1829; Cuvier 1817, *Hist.Nat.Poiss.* XXII.pp 392; Goode and Bean *Oceanic ichthyology* pp 125; Jordan and Evermann *Fishesof Northand Middle America*, pp 603.

Pleurothyris. Lowe, 1843, Hist.*Fishes of Madeira*. pp64. (type *Sternoptyx olfersi* Cuvier, 1829) Invalid synonym.

Characters:

Head and body elevated and compressed, tail narrow, abruptly delimited from the trunk. Body covered with a thin silvery skin. Series of bulls- eye like luminous organ along ventral border of head , body and tail. Nine branchiostegals. Dorsal fin short, situated about the middle of the back, preceded by a thin transparent triangular osseous plate. Anal short . Caudal forked.

Occurrence: Alantic, Mediterranean and Bay of Bengal..

Key to species:

1a. Supra abdominal, preanal, anal and subcaudal photophores in a nearly continuous straight line, distinct gap between each subcaudal phoptophore. . . . . **2.**

1b. Supra abdominal preanal, anal and subcaudal photophores not in a continuous straight line, subcaudal photophores in a continuous gap set off from last anal photophore. . . . . **3.**

2. Photophores form a nearly continuous series from behind pectoral to caudal base. Dorsal blade height less than 1/3rd its length, body margin not markedly raised posterioir to dorsal blade;. . . . . ***A. affinis.***

3.A single ,posteriorly directed serrate ,post abdominal spine;D rays 8 , trunkand caudal region elongate. . . . . ***A. hemigymnus***

4.Post abdominal spine subequal , sub caudal spines absent . . . . ***A. sladeni.***

3.4.1.1 *Argyropelecus affinis*

Figure 3.6

Argyropelecus affinis Garman 1899;237 (Tropical north Atlantic, Lat 15°N 24.40'.Long. 63°31.30'); Norman, 1939. *Norman Murray Exped.* Rep., vol 7 no 1. pp20. (Arabian sea;Gulf of Aden; 400-3840m.); Baird 1971:34; Borodulina. 1978:32;

Argyropelecus pccificus Schultz,1961: 599 Figure 4(Pacific and Indian oceans)Proc. US.Natn. Mus., 112:599, Figure 4.

Total no. of specimens studied: 63.

Diagnostic characteristics:

Dorsal rays 9;Anal rays 12-13;Gill rakers 18-22; subcaudal photophores separate postabdominal spines of equal size with no marked curving ;no subcaudal spines, spine at edge of eye.

Depth of the body 21/5 to 2 3/5. Preopercle with one spine at lower angle, straight or little curved outwards, directed downwards above which is a smaller one directed outwards but not extending past near edge of preopercle; height of dorsal blade, 2 $^{4}/_{5}$ to 3 $^{1}/_{3}$ times in its base. No subcaudal spines. Lower gill rakers 11-12. Length 85mm. Body silvery with well developed pigment markings at myomere borders and midlateral line.

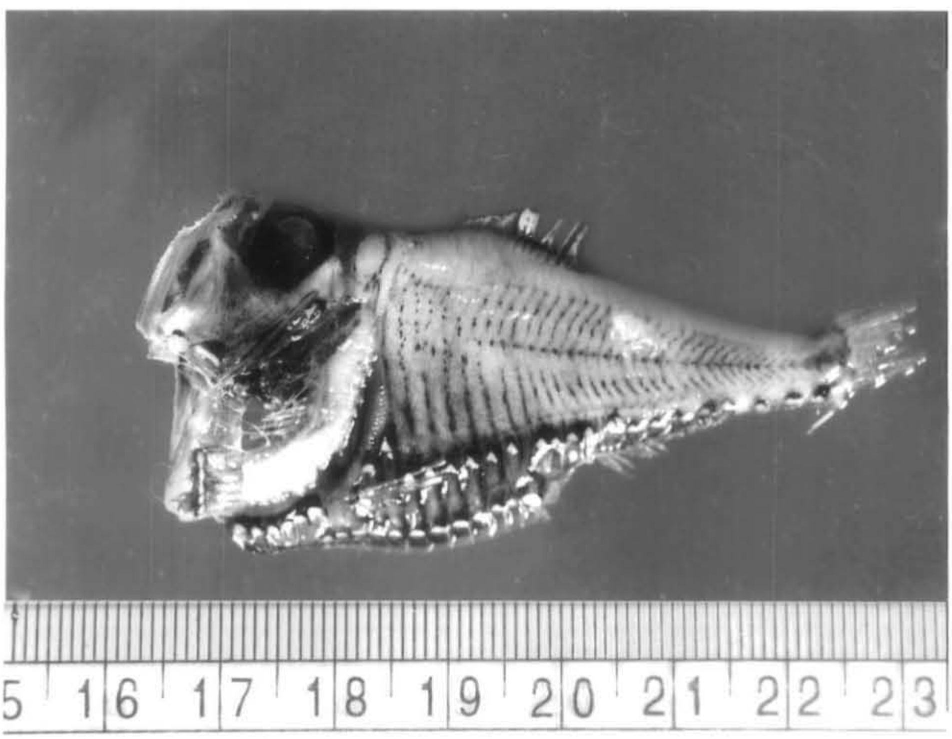


Figure 3.6 *Argyropelecus affinis* (Garman, 1899)

Distribution and Habitat:

Mesopelagic ,170-600m concentrated from 350-600m by day, from 170-400m at night. Occurs in modest abundance in parts of the Gulf of Mexico and Carribbean abundant in the Gulf of Guinea; taken in the Northern Indian Ocean and in the eastern boundary current areas of the Pacific with scattered catches in various other Pacific with scattered catches in varous other Pacific locales. Occurs only occassionally in very low numbers in the eastern Atlantic. Does not exhibit extensive diurnal vertical migration. Widely distributed in all 3 major oceans.

Occurs at Lat. 7°00'-14°00'N and Long. 70°00'-74°00'E in the south west coast of India.

3.4.1.2 *Argyropelecus hemigymnus*

Figure 3.7

Argyropelecus hemigymnus Cocco 1829:146 (Mediterrenean ,Massina);Grindley and Penrith, 1965:282; Baird 1971:42; Hulley 1972:208; Borodulina 1978:37.

Argyropelecus intermedius. Clarke 1878, Trans.Proc.N Zeal.Inst., 10:248 pl 6.

Total number of specimens examined: 9.

Diagnostic characteristics:

Distinctive dwarf species with long narrow tail like trunk. Body bright silvery; dark melanistic pigment changes with time of day, giving body and trunk a more dusky coloration at night. Single characteristic , subabdominal spine with prominent serrations.

Distribution: Rarely exceeds 38mm. Generally found in 500-2000m; little apparent migration; broad world wide distribution. Abundant in the western Mediterranean; found throughout the tropical and temperate Atlantic as well as the Pacific and

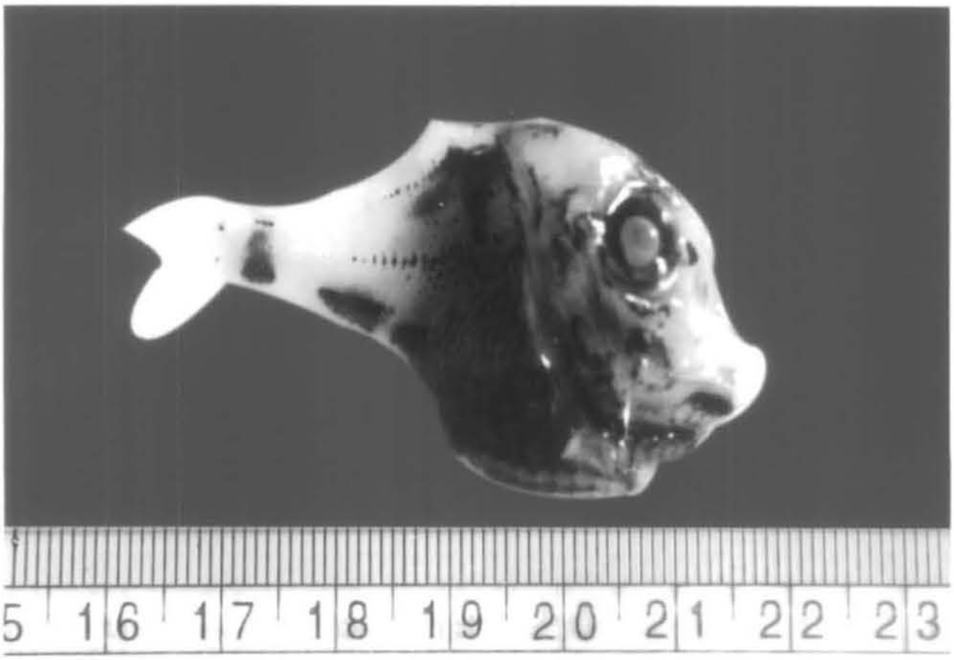


Figure 3.7 *Argyropelecus hemigymnus* (Cocco, 1829)

Oindian Oceans. Catch rates of 203-30 fish per hour with a 10 feet IKMT are not uncommon in the Eastern Atlanbtic and Mediterranean.

Occurs at Lat. 7°N –12°N and Long. 68°-74°E in the south west coast of India.

3.4.1.3 *Argyropelecus sladeni*

Figure 3.8

Argyropelecus sladeni Regan 1908: *Tr. Linn Soc London* Ser2 vol 12 .Zool. Number 14, p218 (Chagos Archipelago, Indian Ocean, 400 fathoms); Norman,1939, Norman Murray Expedition Rep., vol7, Number 1 p20 (Arabian sea, 984m.); Baird, 1971:65; Hecht and Hecht, 1978:202; Borodulina, 1978:45,

Argyropelecus olfersi (Non Cuvier):Barnard:1925.

Number of specimens= 70

Dorsal rays 9;Anal rays 12;Body depth posterior to D2 in SL; dorsal blade low not pronounced; no large canine teeth; Lower preopercular spine straight directed downwards often a little curved outwards, but not forward, upper spine of moderate size, directed outward and backward, sub-caudal spines subequal. Depth 1 3/10 to 1 7/10. Lower preopercular spine straight directed downwards, often a little curved outwards but not forward, upper spine of moderate size, directed outwards and backwards; its tip extending past rear edge of preopercular bone; height of dorsal blade 1 7/10 to 21/3 times in length of its base; subcaudal spines subequal the two spines diverging at angle 45-50°. Lower gill raker 8-10. Reaches a maximum length of 60mm.

Distribution :. Small vertical migration indicated : 100-350m at night, 350-600m by day. World wide reported to 12° S in Indian Ocean. Occurs at Lat 7°-10°N and Long.68°-75°E in the south west coast of India.

Figure 3.8 *Argyropelecus sladeni* (Regan, 1908)

D-317

Genus Polyipnus

Polyipnus Gunther 1887.*Challenger Deep sea fishes* pp170.; Goode and Bean, 1896, *Oceanic ichthyology* pp 128.

Diagnostic characteristics:

Body covered with a thin silvery burnished skin, with large extremely thin excessively deciduous scales. Absence of a abrupt ventral constriction between body and tail. Series of conspicuous luminous organs along the ventral border of the head, body and tail and also on the sides of the head and belly. A series of scutes form a serrature along the mid-ventral line from the pectoral symphysis to the base of the caudal, the series being broken by the ventral and anal fins.

Eyes large and lateral. Gill opening wide, numerous very long gill rakers on the outer side of the first branchial arch. Pseudobranchiae present. Branchiostegals six. Dorsal fin beginning about the middle of the body , rather short, preceded by a small bifurcate spine but not by any large triangular osseous plate. Anal rather short. Caudal forked. Adipose dorsal present. Pectorals well developed, ventrals small. Presence of an air bladder.

Distribution: Tropical Pacific, Andaman Sea.

Key to species

1a Spine complex at posterodorsal margin of head (post temporal bone) bears basal supplementary spines; ventral scales below abdominal photophores serrate. . . . . ***P. indicus***

Polyipnus indicus

Figure 3.9

Polyipnus indicus, Schultz , 1961: 645 Figure 22 (off Zanzibar); Baird 1971:91;

Polyipnus nuttingi (non gilbert): Norman, 1939:20

Total No. of specimens studied: 80.

Diagnostic characteristics:

Dorsal rays 13-14; Anal rays 15-17; Gill rakers 20-22; Major post-temporal spine long and thin, single basal spine very short, frontal bone above eye serrate. Origin of dorsal rays nearly midway of the body preceded by a short bifid spine. Caudal forked.

The arrangement of photophores (A series of six on each side of the Isthmus to the root of the pectoral fin; ten along each side of the ventral edge; five on either side above the level of the pectoral; two on either side of the trunk; five along the abdomen) is the same in *P.indicus* and *P. spinosus*.

Distribution:

Known specimens less than 55mm SL. Mesopelagic species likely found in 50-500m; distribution and abundance not well documented; known only from east African coast from 30° S to 5° N latitude. Occurs at Lat.9°00'N-19°00N and Long. 73°-75°E in the north west and south west coast of India.

Remarks : According to K.S.Misra *P. spinosus* is the only species found in India. From the present study it was seen that *P.indicus* and *P. spinosus* are the same as in both the upper part of the head is narrow ,compressed and conical and is bounded on each side by a serrated ridge that ends in large sharp semi-recumbent spine. Hence *P. spinosus* (Gunther, Challenger Deep sea fishes p.170 ; Alcock. Ann Mag Nat. Hist., Dec. 1889,pp398 and August 1891, pp126. Gilbert and Cramer, Proc US Nat His XIX., 1896, p416.) can be considered as a synonym.

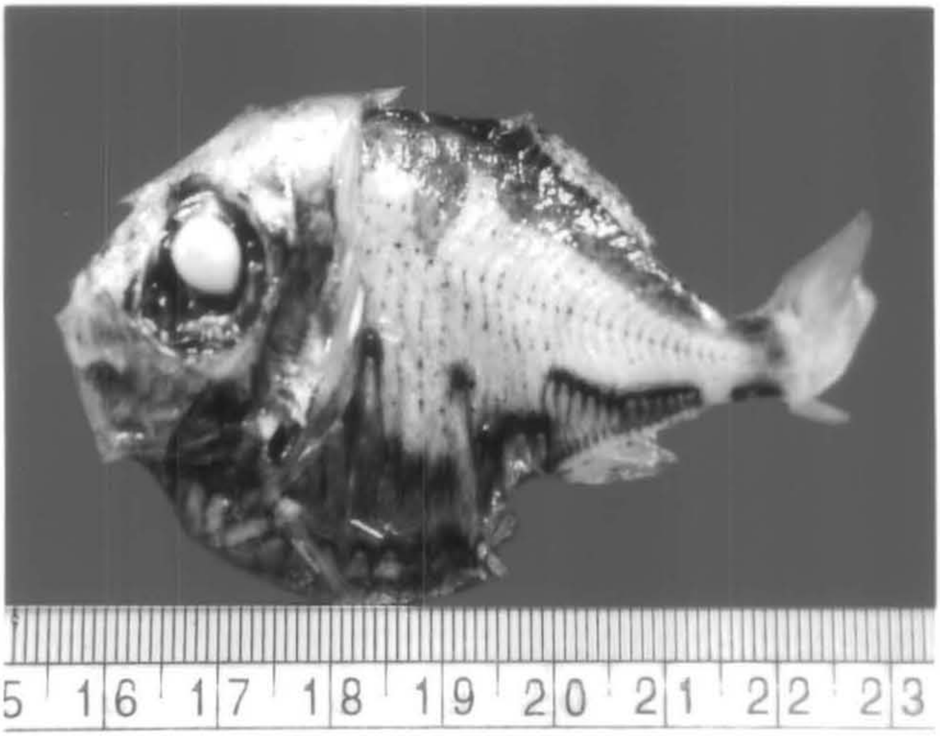


Figure 3.9 *Polyipnus indicus* (Schultz, 1961)

Chapter - IV

Length Weight Relationship

4. LENGTH AND WEIGHT RELATIONSHIP

4.1 Introduction

Length and weight data are useful and standard results of fish sampling programs. They are used for the estimation of weight from length for indivizual fish and for length classes of fish and estimating of standard crop biomass when the length frequency distribution is known. (Anderson and Gutreuter, 1983; Petrakis and Stergiou, 1995). The biomass has been used as an indirect estimate of production and is a prerequsite for calculating poduction using the ricker algebraic method . Biomass is often estimated from length/ weight regressions because direct weight measurement can be time consuming in the field. They are also required for the conversion of growth in length equations to growth in weight for prediction of weight at age and use in stock assessment models (Pauly, 1983). The data are useful for the calculation of condition indices (Anderson and Gutreuter, 1983) and for the study of the life history and morphological comparisons of populations from different regions (Petrakis and Stergiou, 1995) .

Studies on the length weight relationship on the genus *Vinciguerria* (*V. nimbaria,* family:Photichthyidae) have been reported by Menon *et al.,* 1996 and Kalnina *et al.,* 1984. The length weight relationship on *V. lucetia* has been reported by Andrianov and Bekker, 1989. Due to lack of information on the length weight relationship in the Indian waters the present study has been undertaken. The length weight relationship of other deep-sea species have been reported. (Landa, *et al.*, 2001; Beatriz Morales-Nin,2001; Carina Lobo *et al.*, 2001; Kelly *et al.*, 1997).

4.2 Materials and Methods:

The length weight relationship of *Vinciguerria nimbaria* and *V. lucetia* were studied based on 846 specimens collected from IKMT operated from onboard **FORV *Sagar Sampada*** during 1998-2000. The standard length (SL) and total length (TL) were measured to the nearest millimeter. Individual total weight was recorded to the nearest milligram.

The equation used to describe length weight relationship is a allometric function

$$W= aL^b,$$

Where, W is the weight, L is the Length and a and b are constants. A logarithmic transformation of the above equation leads to a linear relationship

$$LogW=loga+b\ logL$$

that can be estimated with minimnal computing powers, by using least squares.

The significance of the regressions of the length weight equation expressed lograthimically was tested for possible significant differences ($P<0.05$) between males and females by using analysis of variance test for homogeinity of slope.

The 't' test (Snedecor and Cochran, 1967) was used to test whether the regresssion coefficents significantly deviated from the expected cubic value.

4.2.1. Length frequency distribution:

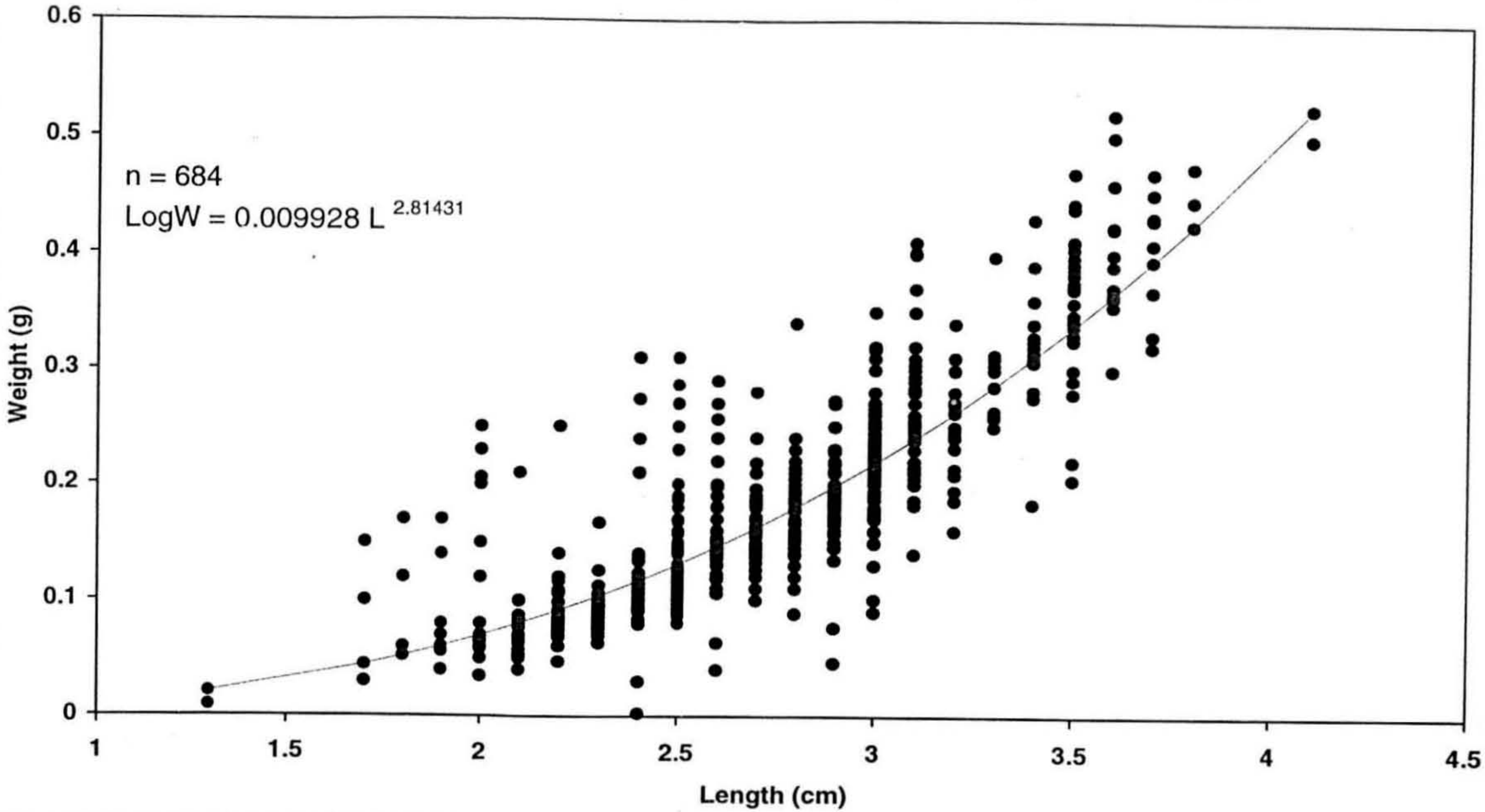
The length frequency distributional studies monthwise was done for *V.nimbaria* and *V. lucetia* respectively. The specimens were grouped under the following length groups i.e., 10-19mm, 20-29mm, 30-39mm and 40-49mm.

4.3 Results

4.3.1 *V. nimbaria*

A total of 370 males and 350 females representing the species *V. nimbaria* were measured sexed and weighed. The length ranged from 10mm to 50mm . The Length weight relationship is shown in Figure 4.1...

Figure 4.1 Length-Weight relationship of *Vinciguerria nimbaria*



The length weight relationship for *V. nimbaria* was estimated as

Males : Log W= -4.54716+2.73706 (r=0.745464)

Females : Log W= -4.66072+2.87625 (r=0.873133)

Pooled : Log W= -4.61236 +2.81431 (r=0.811764)

To test the equality of Length weight relationship between males and females the Analysis of variance (ANOVA) was carried out. (Table 4.1)

Table 4.1 Test of Equality of regression lines (*V. nimbaria*)

Source	DF	SS-X	SP	SS-y	b	DF	SS	MS	F
Males	361	7.8525	21.4949	105.852	2.737	360	47.031	0.13064	
Females	321	9.8889	28.4429	107.309	2.876	320	25.501	0.07969	
Total						680	72.532	0.10666	
Pld W	682	17.7414	49.9357	213.1676	2.815	681	72.617	0.10663	
Difference between slopes						1	0.085	0.0848	0.8
Between	1	0.0003	-0.005	0.078					
W+B	683	17.7417	49.8307	213.2456	2.814	682	72.725	0.10663	
Difference between corrected means						1	0.108	0.10846	1.02

Source	Mean-X	Mean-Y	a	b	r
Males	0.998	-1.816	-4.547	2.73706	0.745464
Females	0.996	-1.795	-4.661	2.87625	0.873133
Pooled	0.997	-1.806	-4.612	2.81431	0.811764

The calculated value at 0.80 was less than table value at L∝=3.84.Thus the ANOVA analysis showed that there was no significant difference in slope or intercept of the length weight relationship between the males and females and thus one equation calculated with the sexes combined was used to represent the data.

Exponential form of the equation

$W= 0.00992339\ L^{2.81431017}$

$\text{Log } W=\text{Log } 0.00992839 + 2.81431017 \text{ Log } L \quad (r = 0.81)$

The linear regression obtained from log transformed were significant i.e.,$P<0.001$. The scatter diagram of observed values of wt (g) against T.L (cm) are given in Figure 4.1. The Length Weight Relationship was found to be isometric for the pooled data.

The significance of variation in the estimates of 'b' for this species from the expected value for ideal fish (3.0) was tested by 't' test and the the result was

Pooled = –40.840699 (non significant)

4.3.1.1 Length frequency distribution:

The length frequency distribution in different months in *V. nimbaria* is as shown in the Figure 4.2 (a-f). In April a high percentage were seen in the length ranges from 30- 30 and 40-40mm. In May they occurred at a higher percentage at length ranges of 30-39mm. In July a high number of juveniles were seen from 10-29 mm. In October and November the species occurred at the length range of 20-39mm. In December all were seen at 10-19mm.

4.3.2 V. lucetia

A total of 89 males and 73 females of *V. lucetia* was measured sexed and weighed. The length ranged from 10mm to 50mm . The Length weight relationship is shown in Figure 4.3)

The length weight relationship for *V. lucetia* was estimated as

Males: Log W=-4.97734+3.08257 (r=0.943)

Females: Log W= -5.10423+3.25289 (r=0.87)

Pooled: Log W= -5.03848+3.16450 (r=0.91)

Table 4.3 Length frequency of *V. nimbaria* at different months

	April	May	July	October	November	December
10-19mm			31.66			35
20-29mm	22.22	32	36.66	31.66	30	27.5
30-39mm	77.78	68	30	41.39	40	25
40-49mm	38.89		1.6	26.11	30	12

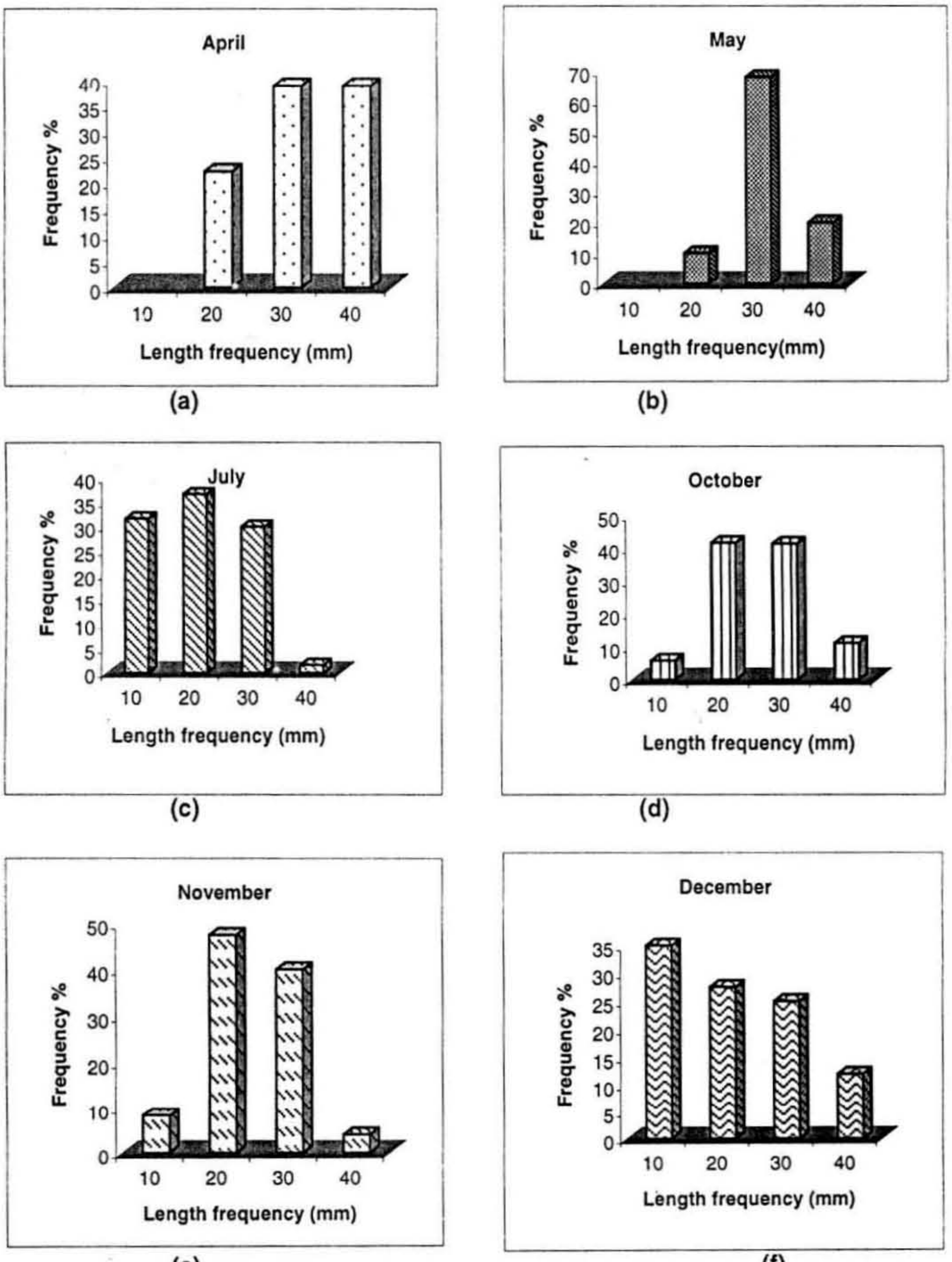


Fig. 4.2 Length frequency distribution of *V. nimbaria* (a, b, c, d, e, f)

To test equality of Length weight relationship between males and females the Analysis of variance (ANOVA) was carried out. (Table 4.3)

Table 4.3 Test of Equality of regression lines (*V. lucetia*)

Source	DF	SS-X	SP	SS-y	b	DF	SS	MS	F
Males	88	2.1854	6.7366	23.3176	3.083	87	2.552	0.02933	
Females	72	1.357	4.4142	18.6266	3.253	71	4.268	0.06011	
Total						158	6.819	0.04316	
Pld W	160	3.5424	11.1507	41.9443	3.148	159	6.844	0.04304	
Difference between slopes						1	0.024	0.02428	0.56
Between									
W+B						160	6.934	0.04334	
Difference between corrected means						1	0.09	0.08998	2.09

Source	Mean-X	Mean-Y	a	b	r
Males	1.005	-1.878	-4.997	3.08257	0.943699
Females	1.037	-1.732	-5.104	3.25289	0.877996
Pooled	01.019	-1.812	-5.038	3.1645	0.915422

The calculated value at 0.56 was less than table value at L∝=3.84.Thus the ANOVA analysis showed that there was no significant difference in slope or intercept of the length weight relationship between the males and females and thus one equation calculated with the sexes combined was used to represent the data..

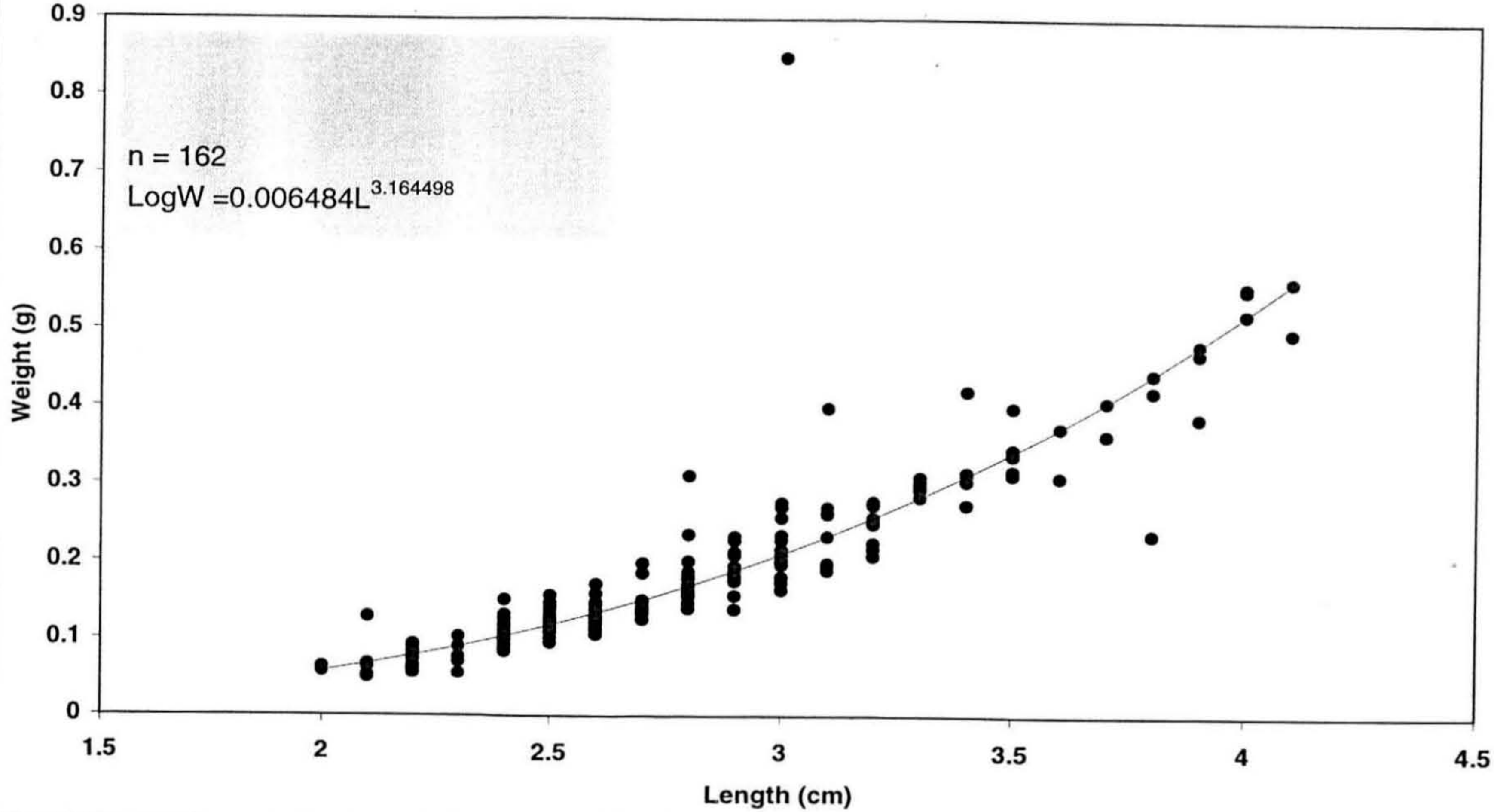
Exponential form of the equation

$$W= 0.006483607\ L^{3.164497613}$$

$$\text{Log } W=\text{Log } 0.006483607 + 3.164497613 \text{ Log } L \quad (r = 0.91)$$

The scatter diagram of observed values of wt (g) against T.L (cm) are given in Figure 4.3. The significance of variation in the estimates of 'b' for this species from the expected value for ideal fish (3.0) was tested by 't' test and the the result was

Figure 4.3 Length-Weight relationship of *V. lucetia*



Pooled = 14.522 (significant)

The LWR was not found to be isometric for the pooled data.

4.3.2.1 Length frequency distribution

The length frequency distribution showed that in the month of May the occurrence of indivizuals were in the length range of 30-39mm. In July were seen in the length range till 39 mm at varied percentages. In November all were present in length ranges from 20-49mm. In December all the species were at length groups of 20-39mm.

4.4 Discussion

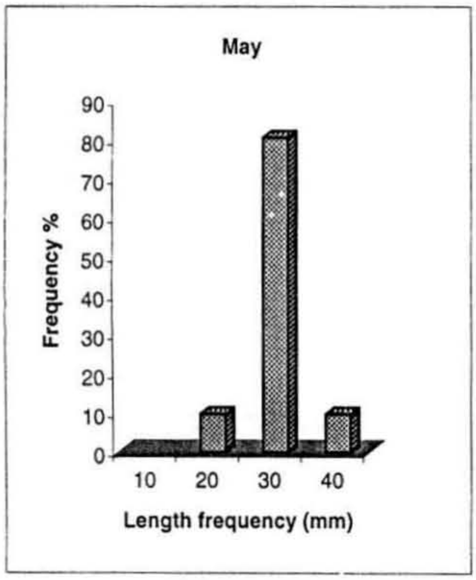
The present results showed that the length weight relationship in *V. nimbaria* and *V. lucetia* was positively correlated. The P values was greater than 0.001 in both the species studied. The relationship W= al^b has been used in mesopelagic fishes and deep sea fishes (Kalnina *et al.*, 1984;Thomas *et al.*, 1988 ; Andrianov and Bekker, 1989; Menon *et al.*, 1996; Kelly *et al.*, 1997; Land, *et al.*, 2001; Beatriz Morales-Nin,2001; Carina Lobo *et al.*, 2001; Klara *et al.*, 2001).

Thomas *et al.*, 1988 on their work on the mesopelagic fish *Gonostoma elongatum* showed that the length between males and females did not differ significantly. Menon *et al* .,1996 showed the relationship of *V. nimbaria* to be Log W=-5.5691+3.176 log L (r=0.9830).

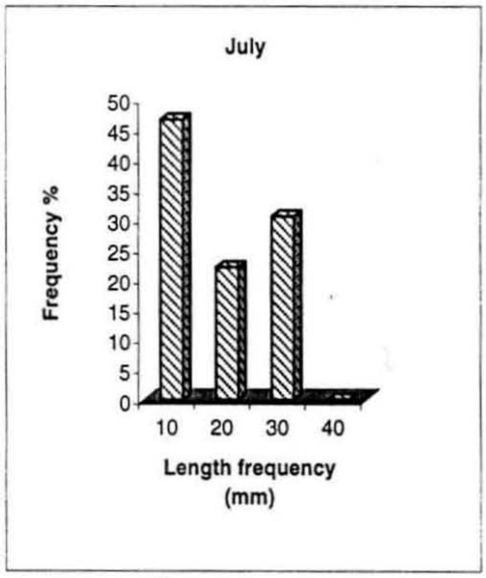
Andrianov and Bekker ,1989 showed that the length of *V. lucetia* ranged between 10 and 51mm (24.55mm on average) whereas weight ranged between 30 and 1100 mg (243 mg on the average). Females were slightly larger than males. The present study confirmed with the above study ,however sexual dimorphism was absent.

Table 4.5 Length frequency of *V. lucetia* at different months

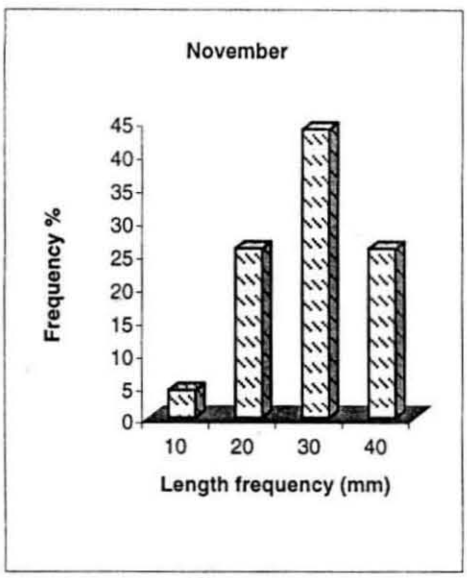
TL	May	July	November	December
10-19mm		46.61	4.4	10
20-29mm	9.76	22.03	25.84	34
30-39mm	80.49	30.5	43.82	46
40-49mm	9.76	0.01	25.84	10



a



b



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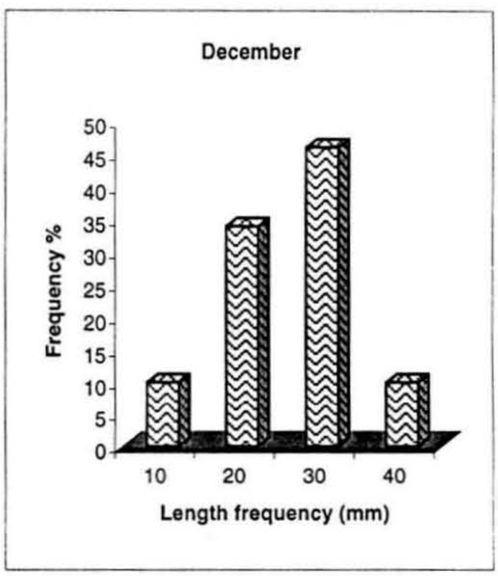


d

Fig. 4.4 Length frequency distribution of *V. lucetia* (a to d)

The analysis of variance revealed no significant difference between the males and females of both the species studied. Thus a commom equation for the length weight relationship was considered.

The length frequency distribution in different months in *V. nimbaria* showed that in April and May a high percentage were seen in the length ranges from 30- 39 and 40-49mm. In May they occurred at a higher percentage at length ranges of 30-39mm. In July a high number of juveniles were seen from 10-29 mm. In October and November the species occurred at the length range of 20-39mm. In December most were seen at 10-19mm.

The length frequency distribution in *V. lucetia* showed that in the month of May the occurrence of indivizuals were in the length range of 30-39mm. In July were seen in the length range till 39 mm at varied percentages. In November all were present in length ranges from 20-49mm. In December all the species were at length groups of 20-39mm. The variation in the percentage of occurrence of the fishes in the various sizes and during different seasons of study is related to the sexual cycle in Vinciguerria. Menon (1990) showed that occurrence in different length groups is related to the spawning.

Chapter - V

Food And Feeding

5. FOOD AND FEEDING

5.1 Introduction:

Food sources for deep sea communities have been a subject of speculation for many years (Zenkevich and Birstein, 1956; Sokolova, 1959; Sanders and Hessler, 1969; Grassle and Sanders, 1973). Energy has to be transported from the euphotic zone to the bottom. Fishes are among the largest and most mobile of deep sea organisms and occupy the highest trophic levels in marine food webs. Therefore fishes should be among the most obvious taxocoenes to reflect major differences in energy transport to ecosystems. These differences my be manifested in various ways such as diet, morphology or behaviour or by differences in community structure.(Musick,1976). Food of deep sea fishes has received some attention in recent years (Merrett and Roe,1974). Stomach contents of some species have been reported cursorily in taxonomic and other work. (Marshall, 1954; Nielsen,1964; Marshall 1965; Robins 1968; Marshall and Iwamoto,1973;). Bright (1970) examined the stomachs of many species of deep sea fishes from the gulf of Mexico and constructed the food web based on data from 81 small species. Pearcy and Ambler (1974) have discussed the significance of pelagic food in the stomachs of some deep living demersal fishes.

Incident light being an important factor aiding vision, the mesopelagic fishes fishes are adapted to specific photic conditions and feed by day or night. Nocturnal feeders emerge from their shelters in large numbers about 30 minutes after sunset and migrate to distant feeding grounds. (Gosline, 1965;Hobson, 1972; Gladfelter 1979). Similarly a transition is also observed in the zooplankters when they emerge in large numbers during late twilight. They include the holoplankters that had been in swarms close to benthic substrata during the day; mostly copepods and mysids (Hamner and Carleton 1979) and at nightfall disperse in the water column. Apart from these a variety of bottom dwelling organisms such as polychaetes, ostracods, isopods, amphipods and crustacean larvae also enter the water column. The highest concentration of the potential prey organisms occur in the upper mixed layer of the open ocean, but developing larvae of the species must move progressively to much greater depths (Loch, 1980) where only low concentrations of potential prey exist. This suggests that mesopelagic fish larvae may not require high concentration of prey for survival and growth and may be less dependent on productive processes in the surface layers.

V.nimbaria is a common mesopelagic species. This species is distributed in the tropical and sub tropical regions of the world oceans. There are reports on its spatial and vertical distribution and reproduction (Grey,1964; Gorbunova,1982; Kubota and Kawamura, 1972).Information on the feeding of the genus *Vinciguerria* in the Pacific and the Indian Oceans has been reported in several publications. (Legand and Rivaton, 1969; Legand *et al.,* 1972; Roger 1980 Ozawa *et al.*,1977; Clarke 1978; Kawamura and Hamaoka, 1982; Kalnina and Shevchenko;1984, Menon *et al.*, 1996). It was reported that Vinciguerria feeds on small and medium sized copepods found in the epipelagic zone, in the 0-200m layer, and seasonal and local changes have also been found. The stomach contents of mesopelagic fish have only recently been correlated closely with diurnal rhythm of migration and feeding.

The study of food and feeding habits is essential for understanding the various aspects of biology such as growth, development, reproduction and migration. It is often the only means of accessing information of feeding ecology, and a vast number of publications on stomach contents are available. Knowledge on the diet of fishes is important in fundamental community analysis for studies of food webs, trophodynamics, resource partitioning and ecological energetics (Ivlev, 1961 and Landenberger 1968). Also an understanding of the relationship between fishes and food organisms and their seasonal distribution will be helpful in understanding the trophic relations in the Oceans

In this chapter the results of the studies on the food and feeding habits of *V. nimbaria* and *V. lucetia* are presented. The material for study was collected from the IKMT operated onboard **FORV *Sagar Sampada*** during 1998-2000.

A composite index known as the 'Index of preponderance' formulated by Natrajan and Jhingaran (1961) takes into account both the occurrence as well as volume (quantity) providing a definite and measurable basis for counting different food items. This method is found to be useful for studying the food habits of carnivorous fishes and many workers from India have adopted this method. Since the prevailing high temperature in tropical waters accelerates the digestion process, the food remains in a recognizable state more in the stomach than in the gut. Hence the diet studies are to be made from the stomach and the rest of the gut could be ignored unless they are special reasons for doing so. (Qasim, 1972)

5.2 Materials and methods

Based on usual examination of the distension of the stomach and the amount of food contained in them they were graded as full , $3/4^{th}$ full, ½ full, $1/4^{th}$ full, trace and empty and assigned points 100,75,50,25,10 and 0 reepectively. After cutting open the stomach the contents were emptied into a petri dish and the food items were identified as far as possible upto generic or species level and their individual volumes were measured by the displacement method. The feeding intensity of the fish was analysed. The fishes with full , $3/4^{th}$ full and half stomachs were categorized as actively fed, and fishes with $1/4^{th}$ full and trace stomachs as poorly fed. Diet components and feeding intensity was done in relation to day and night variation, sexes, size groups,spatial, bathymetric (horizontal and vertical) and temporal.

The month wise data for the west coast cruises of the **FORV *Sagar Sampada*** from May'98 to May 00' were pooled together for arriving at a gross picture of the diet.

The Index of preponderance method of Natarajan and Jhingaran (1961) expressed as

$$I = \frac{Vi*0i}{\Sigma Vi*0I} *100$$

was employed for the food analysis where Vi and Oi are the volume and occurrence indices of food items respectively presented in percentage. Comparing the percentage of food items in the distribution and the abundance of forage in the catch generally arrives at selectivity of food organisms by fishes.

5.3 Results

The study on the stomach contents and feeding habits of *V. nimbaria* and *V. lucetia* was carried out. The particulars on the composition of food and the feeding intensity diurnally ,spatially, monthly, bathymetrically , temporally, sex wise and size groups was done. The diet composition of genus *Vinciguerria* i.e. *V.nimbaria* and *V.lucetia* (1,200nos) were analyzed. The food items in the stomach of the two species noticed consisted of copepod, ostracod, shrimp, digested matter, euphausids, sagitta and semi digested substances. Copepods had the highest frequency of occurrence (34.62 %) being the major prey items in numbers in both the species . Ostracods formed the important food item (25.30%). Shrimps mainly comprising of the deep sea shrimps also constituted a significant percentage in the diet. Digested matter which consisted of digested substances of shrimps, copepods,ostracods,fish eggs gave an idea of the time in which the feeding took place, was found to be one of the main items present. Other groups like fish juveniles, euphausids, sagitta, pteropod, and amphipod constituted a insignificant percentage in the diet. (Figure 5.1)

5.3.1. Food and feeding habits of *V. nimbaria.*:

V. nimbaria feeds mainly on copepods (38.24%) followed by digested matter (26.52), ostracods (22.19%), shrimps (11.15%), unidentified substances (0.78%), fish juveniles (0.73%), sagitta (0.27%) and euphausids (0.13%). Figure 5.2.

5.3.1.1 Food contents in relation to diurnal variation:

At night the feeding index of preponderance showed that the fish fed more on copepods (42.48) followed by ostracods (25.59), digested matter (21.16), shrimps (8.53), fish juvenile (0.87), sagitta (0.31), euphausids (0.22), others (0.85). While in day digested matter (48.31) was dominant followed by copepods (10), ostracods (5). Fish juvenile, sagitta, euphausids and others were absent. The dominance of digested matter during day showed preceeded feeding activity. The day and night variation in feeding is shown in Figure 5.3.

5.3.1.2 Food contents in Males ,Females and Indeterminates

The percentage of the food items present in the males, females and indeterminates showed many variations. Copepods ranked first in males (32.80) and females (40.38). Ostracods ranked second in males (27.94) and third in females (13.69). Digested matter ranked third in males (25.88) and second in females (33.78). Shrimps ranked fourth in males (12.05) and in females (8.80). Fish juvenile, sagitta, euphausids and others were more in females (3.38) and fewer in males(1.33). In juveniles copepods ranked first (57.26), followed by ostracods (32.82), shrimps (4.33, digested matter (4.34) and fish juvenile sagitta, and others were seen in minor proportions.(1.26). (Figure 5.4).

5.3.1.3 Food contents in relation to different latitudes

The species was found to feed most on copepods at Lat 18°N (62.49). Ostracods were dominant at Lat.19°N (53.00). Fish juveniles were dominant at

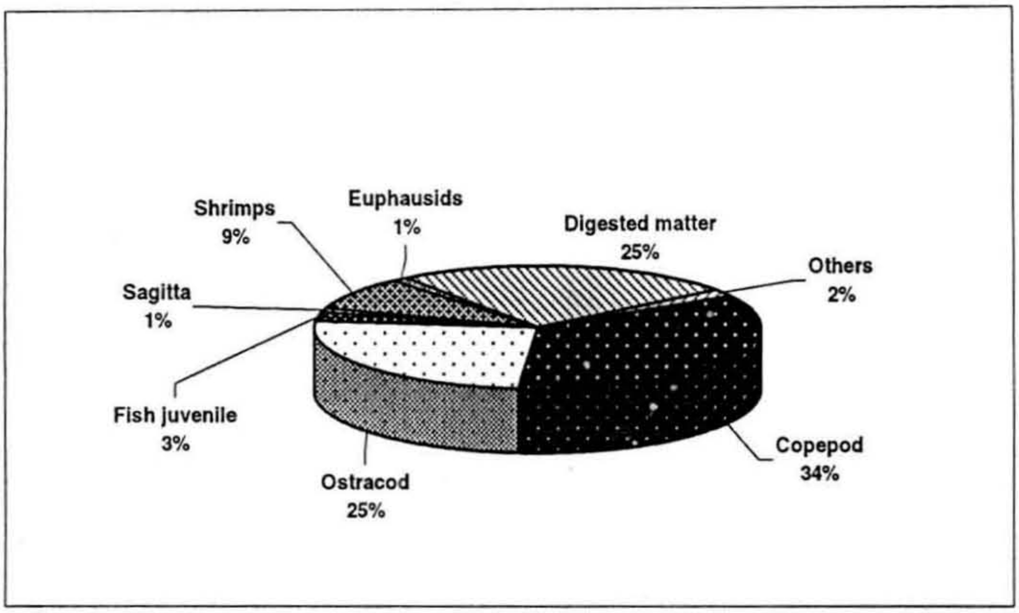


Figure 5.1 Food items of the genus *Vinciguerria*

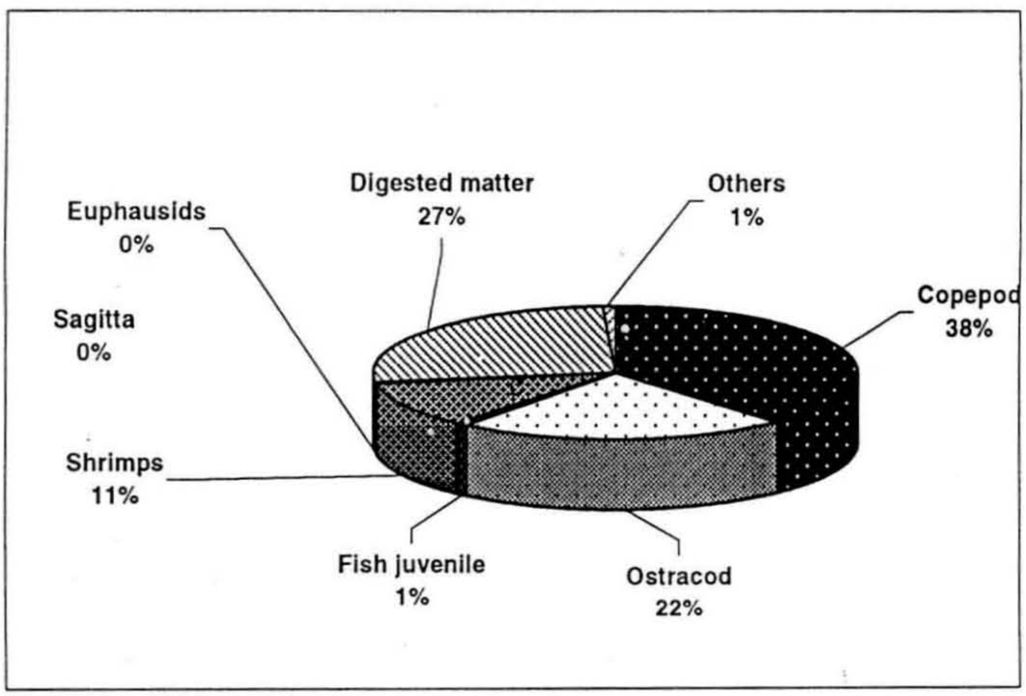


Figure 5.2 . Relative importance of food items in *V. nimbaria*

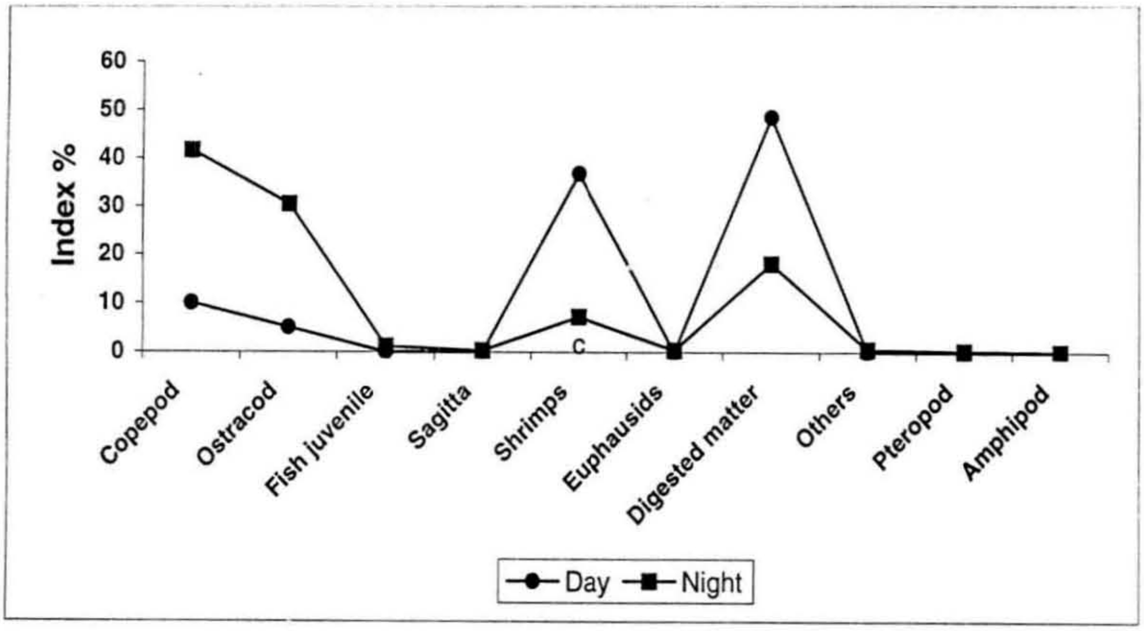


Fig. 5.3 Diurnal Variation in feeding in *V. nimbaria*

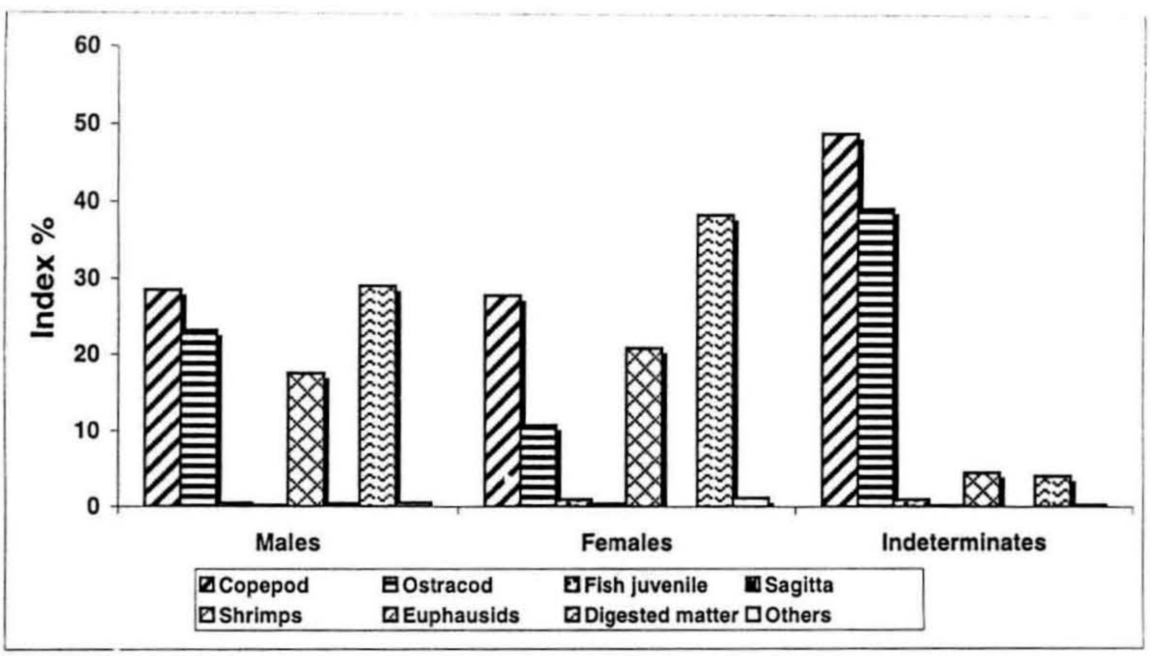


Figure 5.4 Food contents in males, females and Indeterminates in *V. nimbaria*

Lat.19°N (0.45). Sagitta were dominant at Lat.15°N (0.39). Shrimps were dominant at Lat.17°N (24.35). Euphausids were dominant at Lat.12°N (1.27). Digested matter occurred at Lat.7°N (100%) and was absent in Lat.20°N. Others (amphipods, pteropods, fish eggs etc) were maximum at Lat 18°N and least in Lat.10°N (0.56). (Figure.5.5)

5.3.1.4. Month-wise variation in food contents

In most months (except in April and October) of study copepods and ostracods were found to be the most dominant food item in the diet. In the months of April and October digested matter was seen to be ranked first showing preceeded feeding .

April: Food of *V.nimbaria* in this month mainly composed of digested matter (40.13) followed by shrimp's (38.60) and copepod (21.28). The other items were absent.

May: Copepods were found to be the main food item (58.97) followed by digested matter (19.37), ostracods (15.39), shrimps (4.75), fish juveniles (1.49) and others (0.03).

July: The main food item was found to be ostracod (30.39), followed by digested matter (24.38), copepod (24.15), shrimps (19.04). Fish juvenile, sagitta, euphausids and others were seen in a negligible proportion.

October: Digested matter was a main constituent (36.37) followed by ostracods (32.65) and copepods (27.64). Euphausids were absent and other food items were seen in a negligible proportion.

November: Copepods were the main food (48.59) in this month. Ostracods (28.48) were the next preferred item. Digested matter was present at indices of 17.39 and shrimps at 3.19 were the next preferred item. The other items were seen in a negligible proportion.

December: Copepods (48.80) was the main constituent followed by ostracods (26.24) and digested matter. Fish juvenile, sagitta,shrimps, euphausids and others were seen in a minor quantity. (Figure.5.6)

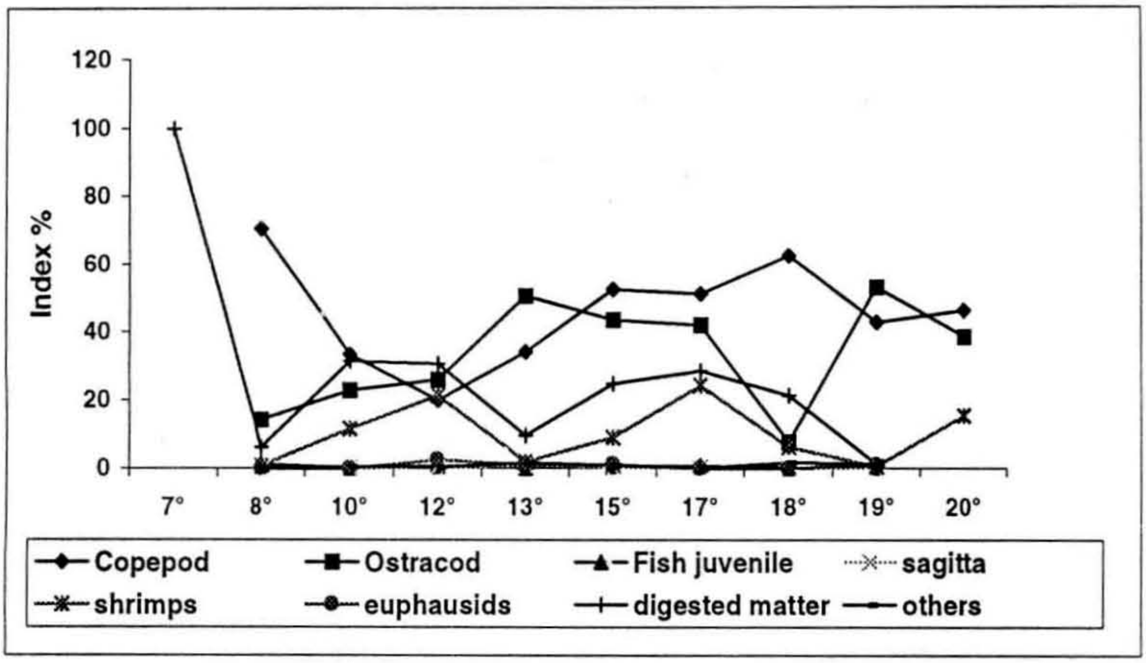


Figure 5.5 Feeding index at different latitudes in *V. nimbaria*

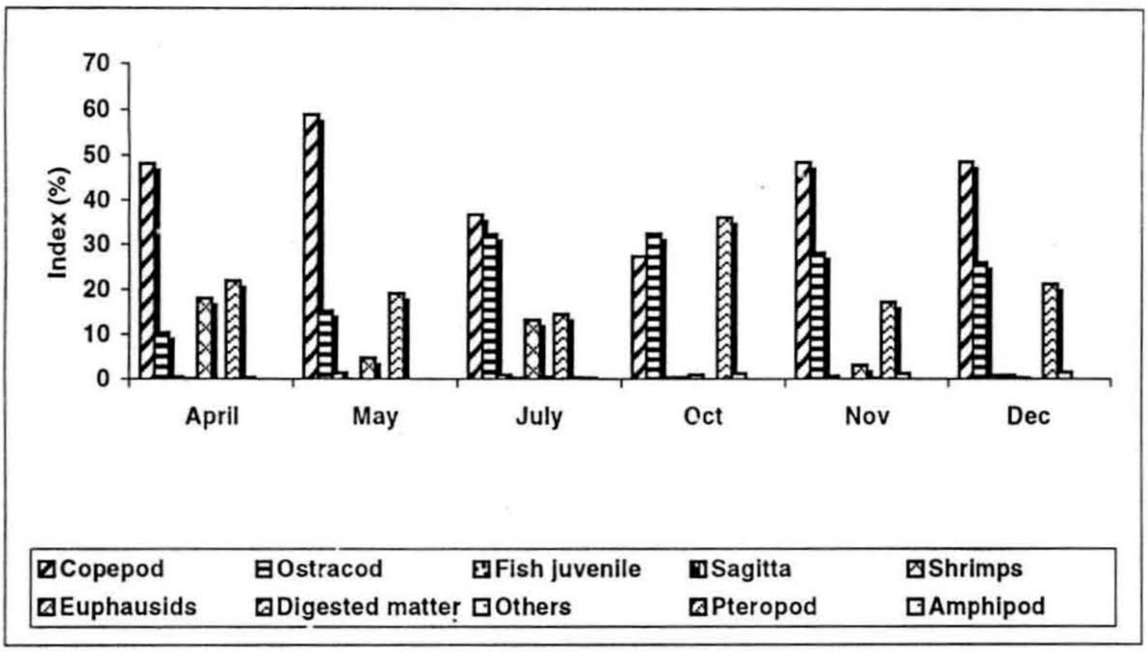


Figure 5.6 Monthly Variation in Food Contents in *V. nimbaria*

5.3.1.5 Seasonal variation in food contents :

In pre-monsoon copepods ranked the highest (37.43) followed by digested matter (30.22), shrimps (21.01), ostracod (10.77). Fish juveniles and others were present in minor quantities. Sagitta and euphausids were absent. In Monsoon digested matter ranked highest (32.69) followed by shrimps (25.73), ostracods (25.39), copepod (14.15), fish juvenile (0.83), euphausids (0.54), others (0.43) and sagitta (0.26). In post-monsoon copepods were first (41.68) followed by ostracods (29.12), digested matter (25.07), shrimps (1.51), fish juvenile (0.69),sagitta (1.51), euphausids (0.07) and others 1.41.(Figure 5.7)

5.3.1.6 Food contents in relation to bathymetric distribution

Vertical variation in feeding of the fishes was significant. The prey found in the stomachs of the fish were dominated by copepods and shrimps in the surface waters till 300m and below that ostracods were found to dominate. There was significant difference of the feeding indexes at different depths during day and night. Thus the diurnai variation is also done to give a better understanding.

The present study showed that at 0-50m copepods (32.71) were the highest followed by digested mater (26.93), ostracods (19.80), shrimps (19.33), fish juvenile (0.61), euphausids (0.32), others (0.25) and sagitta (0.05). At 50-100m digested mater was dominant (44.39), shrimps (22.22), copepods (16.59), ostracods (15.74), others (0.43), euphausids (0.35), fish juvenile (0.18), sagitta (0.11). At 100-300m digested (75.72) and shrimps (24.29) were present. The remaining food items were absent. At above 300m depth ostracods were dominant (43.69), copepods (37.86), digested matter (8.89), shrimps (3.44) others (2.31), fish juvenile (1.8) and sagitta (1.9).The vertical feding index is shown graphically in Figure. 5.8a.

The food contents at different station depths showed that at 0-200m digested matter and shrimps dominated ,at 1000 to depths >3000m copepods and ostracods dominated. (Figure 5.8d)

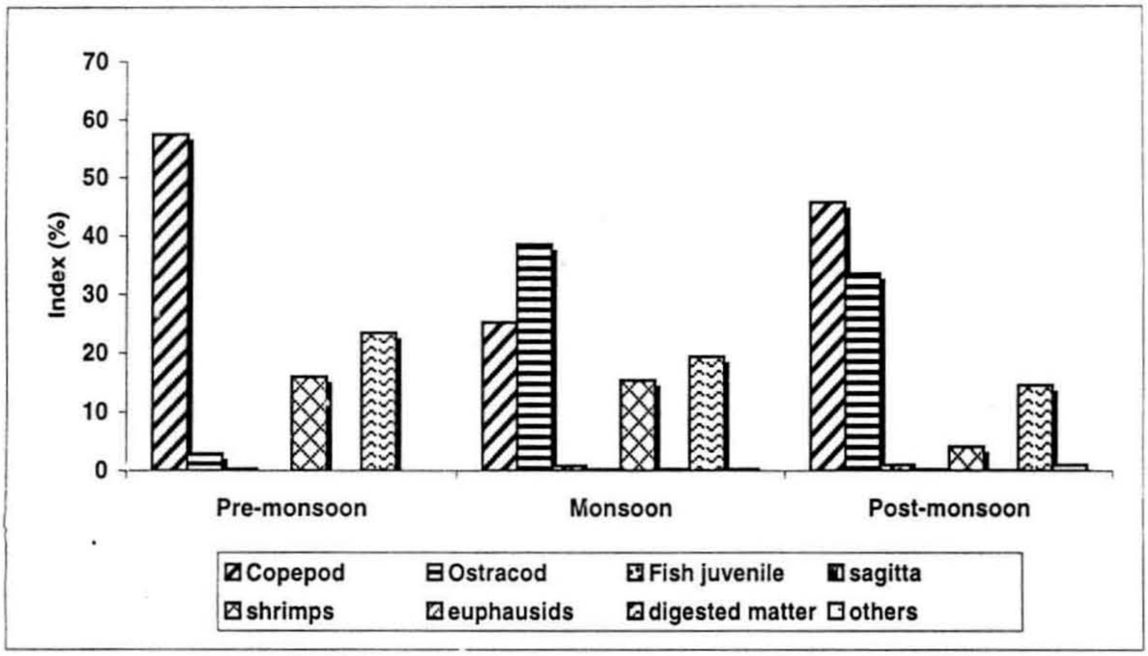


Figure 5.7 Seasonal Variation in Food Contents in *V. nimbaria*

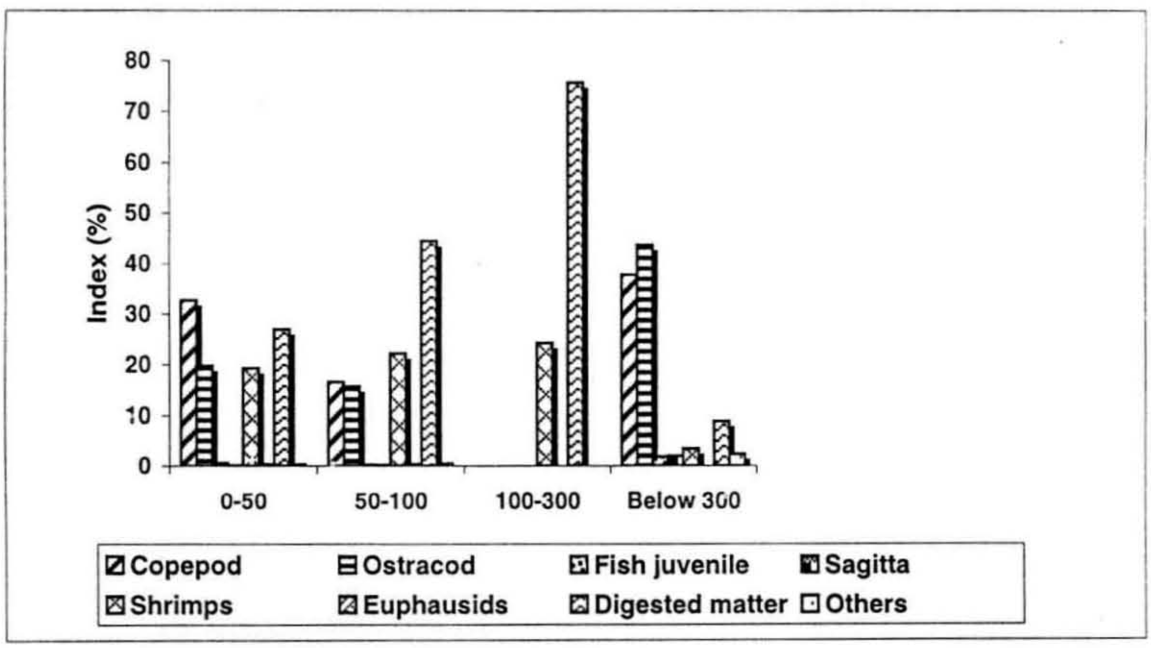


Figure 5.8a Day and Night Vertical Distribution in *V. nimbaria*

5.3.1.6a Vertical variation in food contents diurnally :

0-50m: In day digested matter was dominant (40) followed by shrimps (30), copepod (20), ostracod (10) whereas in night copepods were dominant (45.43) followed by ostracod (29.60), digested matter (13.86), shrimps (8.66), fish juvenile (1.22), euphausids (0.63), others (0.50) and sagitta (0.10).

50-100m: In day digested matter was dominant (61.82) followed by shrimps (38.18), whereas in night copepods were dominant (33.17) followed by ostracod (31.48), digested matter (26.95), shrimps (6.26), fish juvenile, euphausids, others and sagitta were present in minor quantities.

100-300m: In day digested matter was dominant (51.43) followed by shrimps (48.57), whereas in night only digested matter was found.

Below 300m: No day samples were available at night ostracods dominated (43.69)) followed by copepods (37.85), digested matter (8.89), shrimps (3.44), fish juvenile (1.84), others (2.31) and sagitta (1.9) . Euphausids were absent. The day and night variation in feeding is shown graphically in Figure. 5.8b and 5.8c.

5.3.1.6b Horizontal variation in food contents diurnally

The diurnal variation at different station depths showed that during day at 0-1000m shrimps and digested matter dominated while during night from 200m to depths greater than 3000m station depths copepods and ostracods dominated. (Figure 5.8e and 5.8f).

5.3.1.7 Feeding index variation temporally (Hourly):

In the evening hours shrimps were the most common food item, in late night hours copepods followed by ostracods were the food items seen while in early

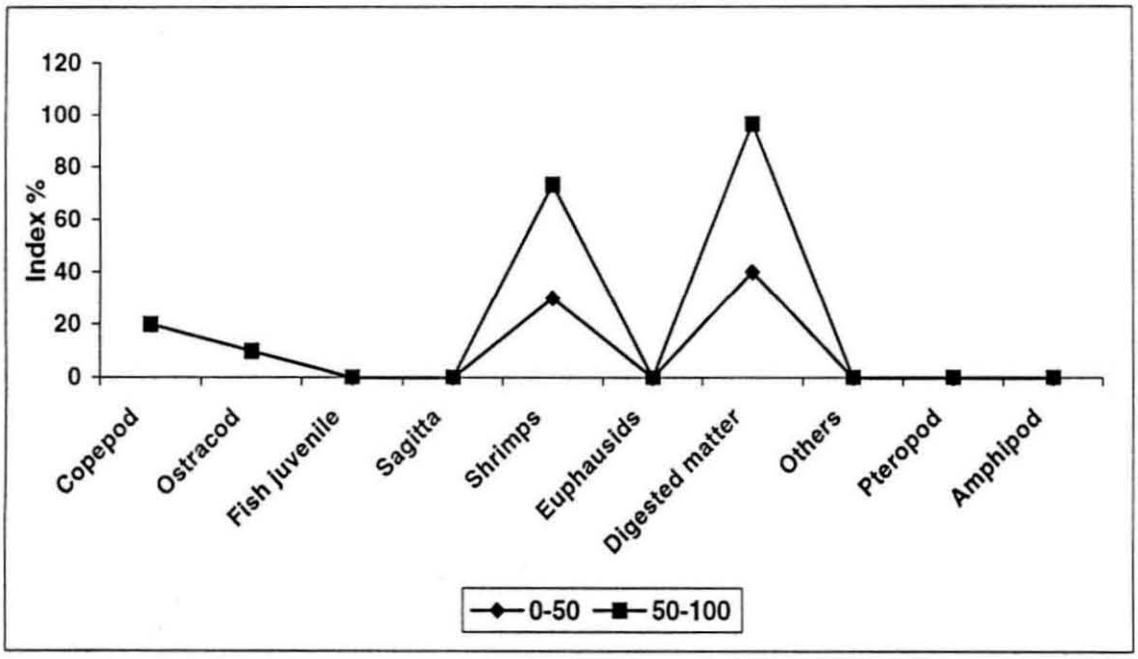


Figure 5.8(b) Vertical Distribution (Day)

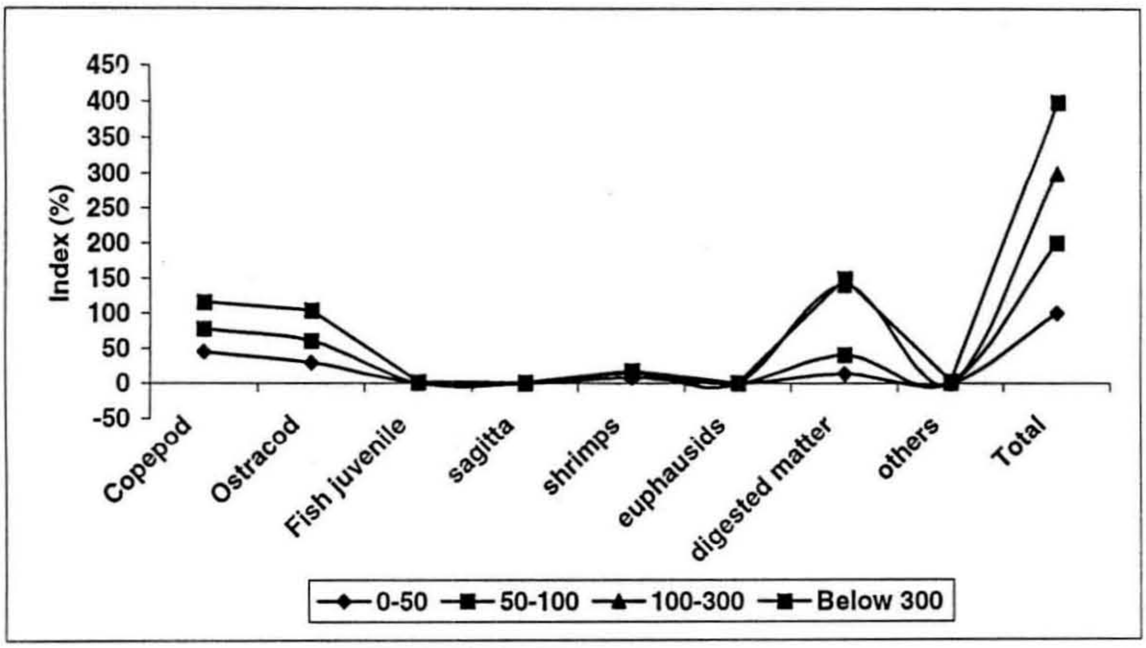


Figure 5.8(c) Vertical Distribution (Night)

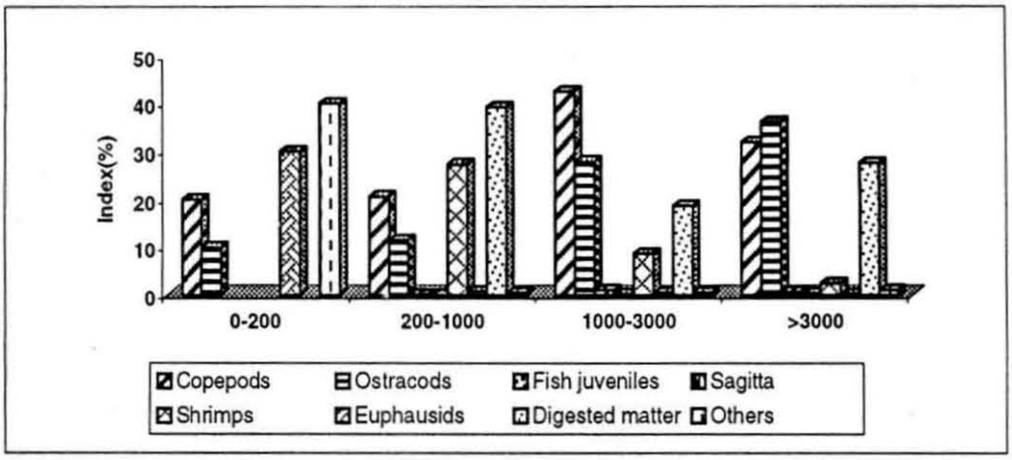


Figure 5.8d Horizontal Variation in Food Contents

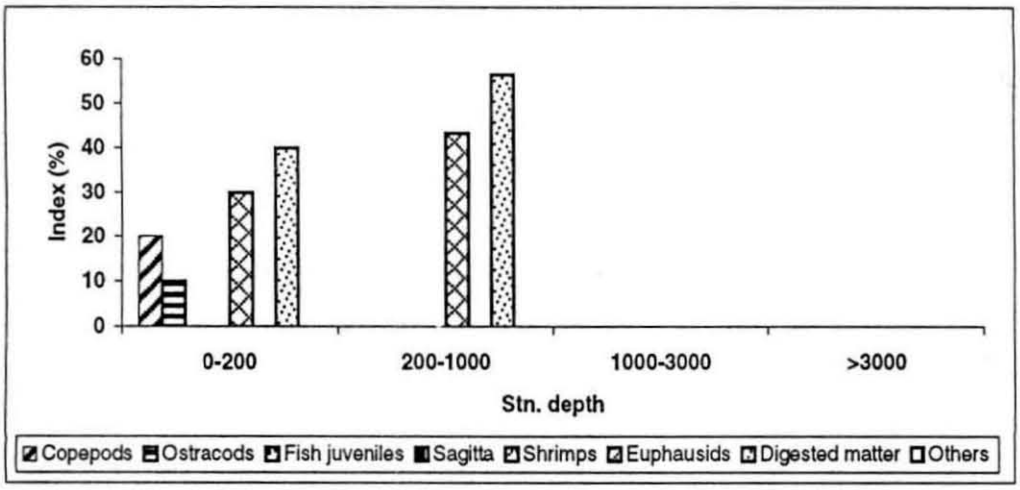


Figure 5.8e Horizontal Variation in Food Contents during day

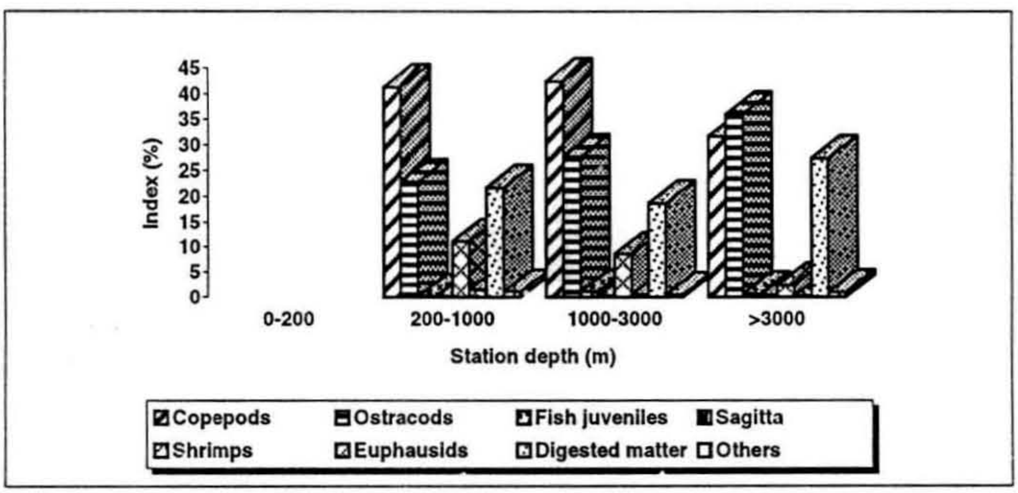


Figure 5.8f Horizontal Variation in Food Contents at Night

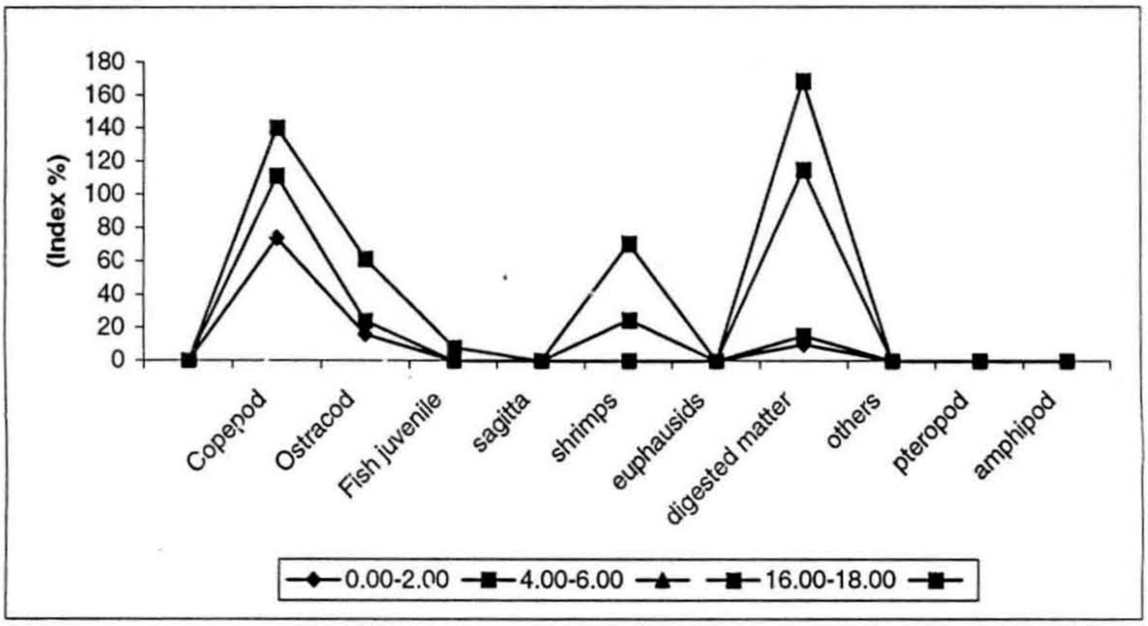


Fig 5.9 Temporal Variation in Food Contents in *V. nimbaria*

morning least feeding took place showing a high percentage of digested matter. (Figure 5.9). The order of preference of the food items at different hours is as follows:

0.00-02.00: At this hour at 0-50m depths, fish mainly feed on copepod (74.12), ostracod (15.89), digested matter (10).
4.00-6.00: The fish is found to have a lot of digested matter (76.98) followed by copepods (17.98), ostracods (4.85), shrimps (0.18).
18.00-20.00: The fish feeds on shrimps (35.37) followed by ostracods (18.96), copepods (14.73), digested matter (26.93), fish juvenile (4.03).
20.00-22.00: At 0-50m the fish feeds most on copepods (41.36) followed by ostracod (25.00), shrimps (0.72), digested matter (15.72). At 50-100m the major constituents were copepods (30.57), ostracod (34.48), digested matter (13.87), shrimps (4.20). Below 300m ostracods ranked first followed by copepods (37.86), digested matter (8.89), shrimps (3.44). The other food items were present in minor quantity.
22.00-0.00: At 0-50m ostracods dominated at (56.61), followed by copepods (40.25), digested matter (1.57) and others (1.57). At 50-100m Copepods dominated at (50.00) followed by digested matter (28.07), ostracods(21.37), and shrimps (0.57).

5.3.2 Food and feeding habits of *V. lucetia* :

V.lucetia feeds mainly on ostracods (31.75), copepods (30.83), digested matter (17.74) and shrimps (6.21). The other food were seen in a lower concentration. (Figure 5.10)

5.3.2.1 Food contents variation in Males, Females and Indeterminates

In males copepods was found to be the most preferred (35.56) while in females and juveniles ostracods were found to be most preferred with indexes at 41.73 and 71.62 respectively. In males the other items in order of their rank were digested matter (25.27)ostracods (16.12), shrimps (7.38), , fish juveniles (5.69), amphipods, pteropods and unidentified (3.51) euphausids (4.94), sagitta (1.52). In females the

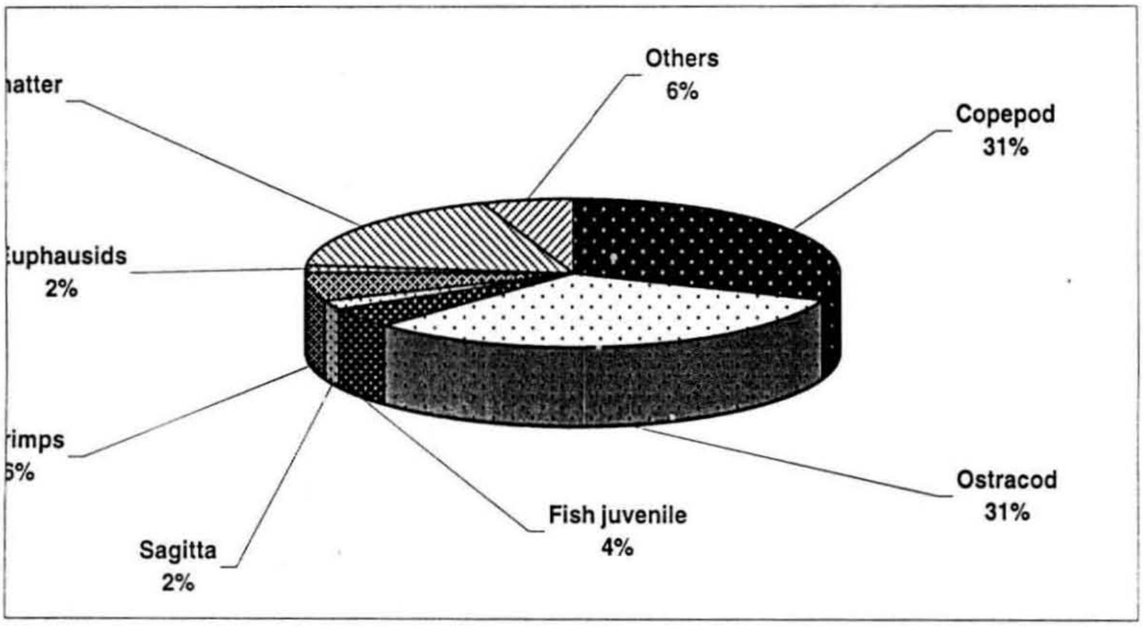


Figure 5.10 Food items in *V. lucetia*

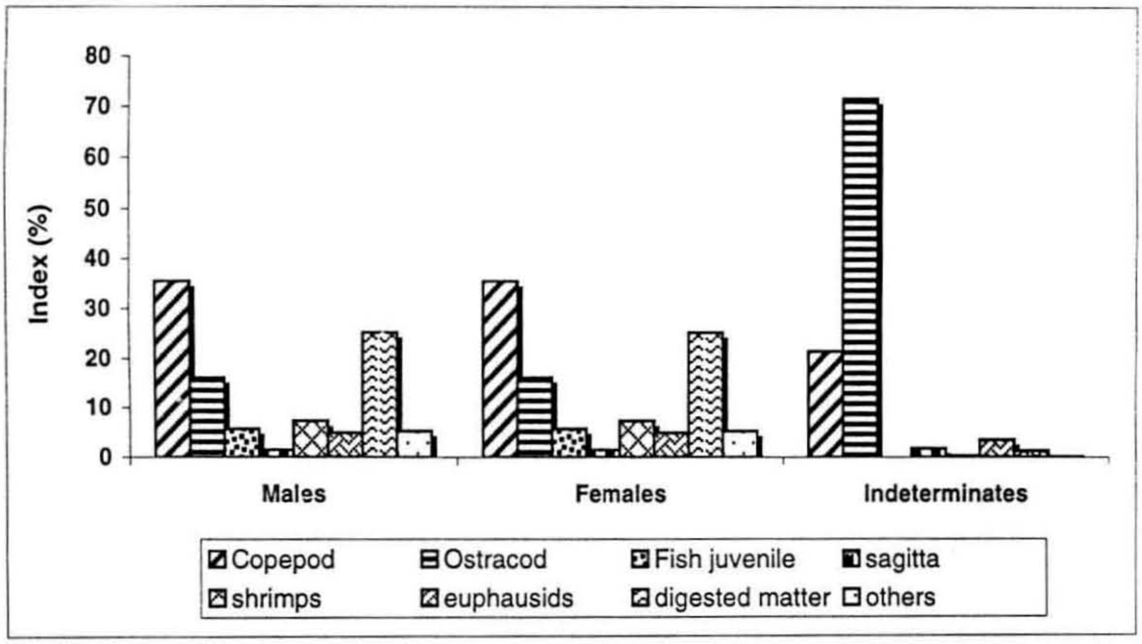


Figure 5.11 Variation in sexes in *V. lucetia*

food items in order of their preference was found to be copepods (28.68), digested matter (18.97), shrimps (6.99). Amphipods, pteropods and unidentified (2.58) and sagitta was taken the least (1.04). Juveniles were seen to feed mainly on copepods (21.48) in addition to ostracods. (Figure 5.11)

5.3.2.2 Spatial variation in food contents

The spatial feeding index of preponderance showed that at all latitudes copepods and ostracods were the most preferred items . Digested matter was found to be highest at 7°showing least feeding . The Saptial feeding index of preponderance is shown graphically in Figure 5.12.

The order of preference of the food items at different latitudes is as follows:

7°: Digested matter was the most dominant (42.86) followed by copepods (16.93), shrimps (16.08), fish juveniles (13.39) sagitta (7.14) ostracods (3.57).
10°: Ostracods were the most preferred (36.52) followed by digested matter (31.83), shrimps (15.74), fish juveniles (6.93), copepod (5.07), others (2.59) and sagitta (0.66).
12° Copepods (47.78) were the most dominant followed by ostracods (31.10), others (10.21), digested matter (5.84), euphausids (4.58), sagitta (0.44), shrimps (0.07).
20°: Copepods (48.23) were the most preferred followed by ostracods (39.85), others (6.50), sagitta (3.49), shrimps (1.94).

5.3.2.3 Month-wise variation in feeding index of preponderance:

In December digested matter was dominant showing less feeding while in the other months of survey ostracods and copepods dominated. The variation is represented graphically in Figure 5.13. The variation in different months is as follows:

April: Samples were not available.
May: Ostracods ranked the highest (34.67) followed by copepod (32.56), shrimps (15.74), digested matter (14.44) and others (2.59).

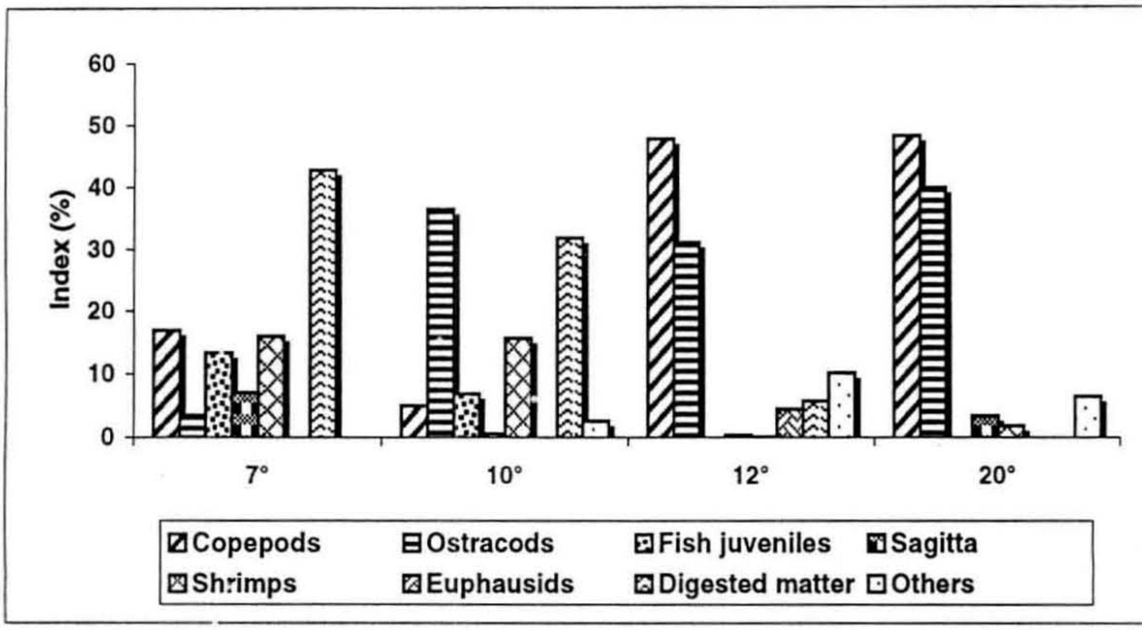


Figure 5.12 Spatial Food components in *V. lucetia*

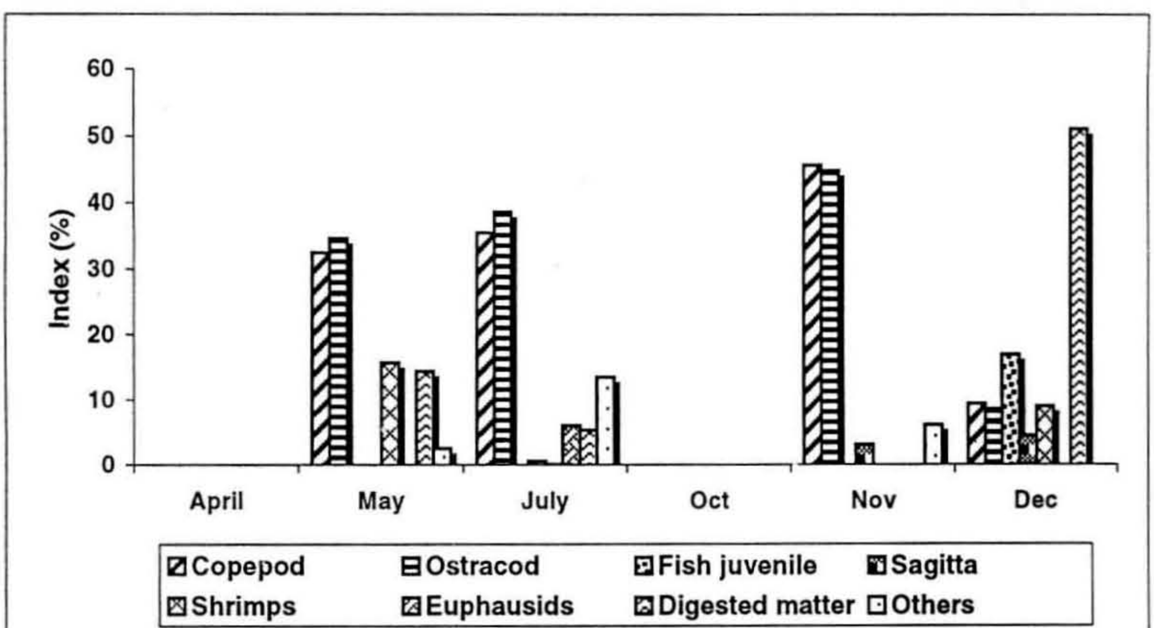


Figure 5.13 Monthly variation in Food Contents in *V. lucetia*

July: The fish feeds most on ostracod (38.69) followed by copepod (35.56), others (13.61), euphausids (6.10) digested matter (5.37), sagitta (0.58) and shrimps (0.09).

October: Samples absent.

November: Copepods were the most preferred item (45.73) followed by ostracods (44.91),sagitta (3.12),euphausids (0.02) and others (6.22) formed a insignificant proportion to the diet.

December: Digested matter (51.14) was the most dominant followed by fish juveniles (17.09), copepods (9.47), shrimps (9.03), ostracod (8.71), sagitta (4.56).

5.3.2.4 Seasonal variation in food contents:

Pre-monsoon: Ostracods dominated at indices of 37.74 followed by copepods at 26.17, shrimps at 17.04 and digested matter at 16.72.

Monsoon: Ostracods ranked highest at 38.69, copepods at 35.69, followed by digested matter (16.48) and euphausids (6.10).

Post-monsoon: Digested matter was dominated (28.68) followed by copepods (27.19), fish juvenile (10.11), Shrimps (4.52), ostracods (4.36), and sagitta (2.29). (Figure 5.14).

5.3.2.5 Food contents in relation to bathymetric distribution:

5.3.2.5a Vertical variation in food contents:

Vertical distribution showed that ostracods and copepods were the preferred items in depth ranges from 0-100m. This is unlike in *V. nimbaria* where copepods were most preferred item at surface when compared to ostracods. The variation in food items vertically is shown graphically in Figure 5.15. The order of preference of food items at different depths is as follows:

0-50: Ostracods (38.69) were the most dominant followed by copepods (35.56), others (13.61), euphausids (6.10), digested matter (5.37), sagitta (0.58), shrimps (0.09).

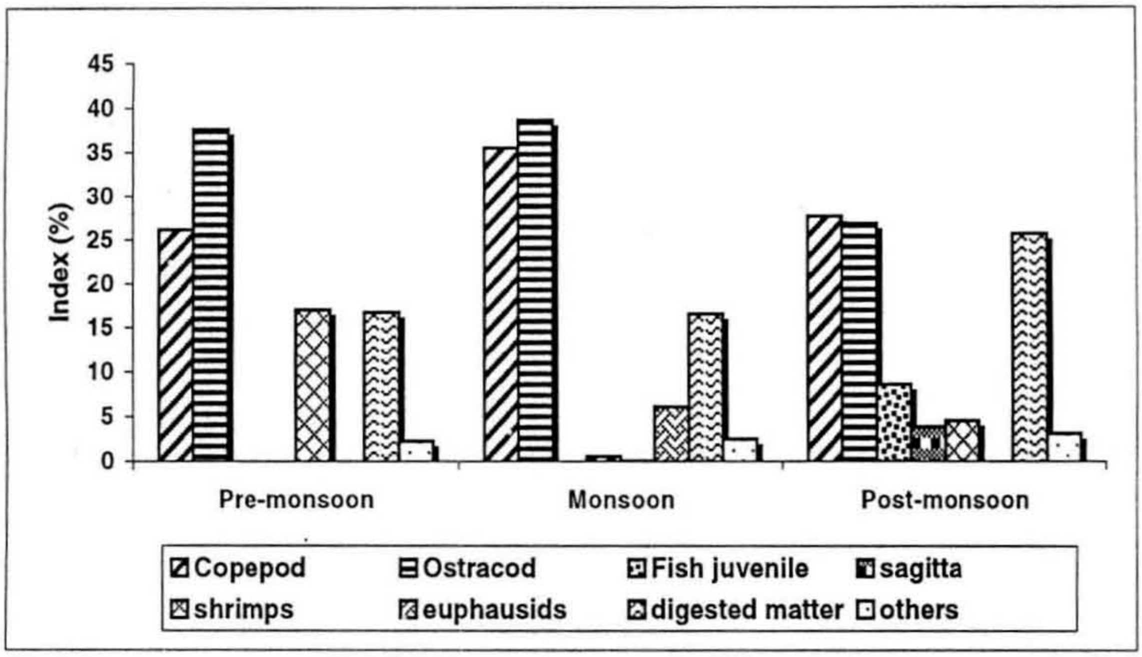


Figure 5.14 Seasonal variation in Food Contents in *V. lucetia*

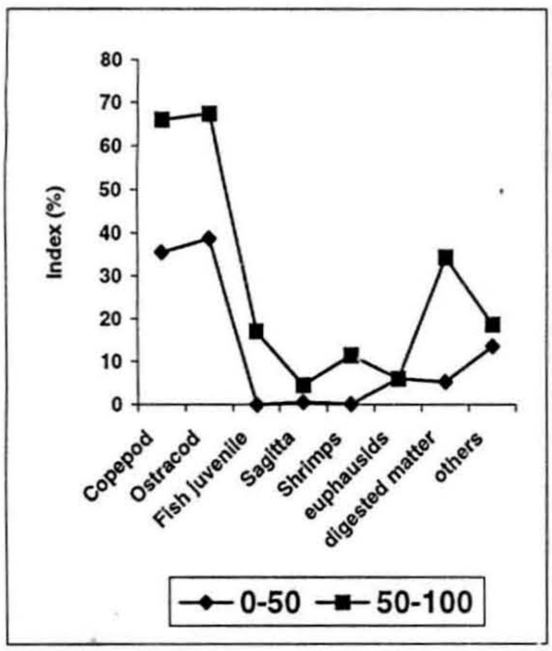


Figure 5.15a Vertical Variation in Food Contents in *V. lucetia*

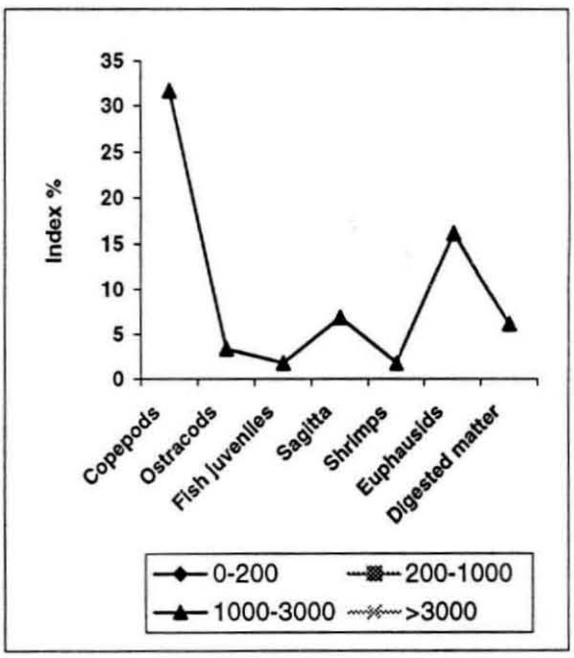


Figure 5.15b Horizontal variation in food contents in *V. lucetia*

50-100: The most dominant food item were copepods (30.44) followed by digested matter (29.12), ostracods (28.73), fish juvenile (17.09), shrimps (11.53, others (5.19) and sagitta (4.03).

5.3.2.5b Horizontal distribution of food contents :

The horizontal distribution of the food contents showed that at 1000-3000m copepods were seen in the diet. (Figure 5.15b)

5.3.2.6 Food in relation to various hours:

The hourly feeding index of preponderance showed that at 20.00-0.00hrs both copepods and ostracods were seen at similar proportions of 33 and 33.71 indexes. (Figure. 5.16).

5.3.3 Feeding intensity of *V. nimbaria*:

The feeding intensity of the fish *V. nimbaria* was generally poor found to be 39.86%. In males the feeding intensity was 50.92%, in females was 36.67%, and in juveniles was32%. The The poorly fed species of *V. nimbaria* were 60.13% , In males 49.07% were poorly fed, in females 63.32%were poorly fed while in juveniles 68% were poorly fed (Figure 5.17). The feeding intensity of the fish has been done diurnally , in relation to sexes, in relation to length, spatially, monthly , seasonally, vertically and temporally. The results are presented below.

5.3.3.1 Variation in feeding intensity diurnally:

Diurnally the feeding intensity was found to be high during night time when compared to day time. During day 70.41 % had empty stomachs while in night only 22.56 % empty stomachs were recorded. During day 97% were poorly fed while during night only 47.83% were poorly fed. The feeding intensity during night was recorded at 52% while at day was recorded at 2%. (Figure 5.18)

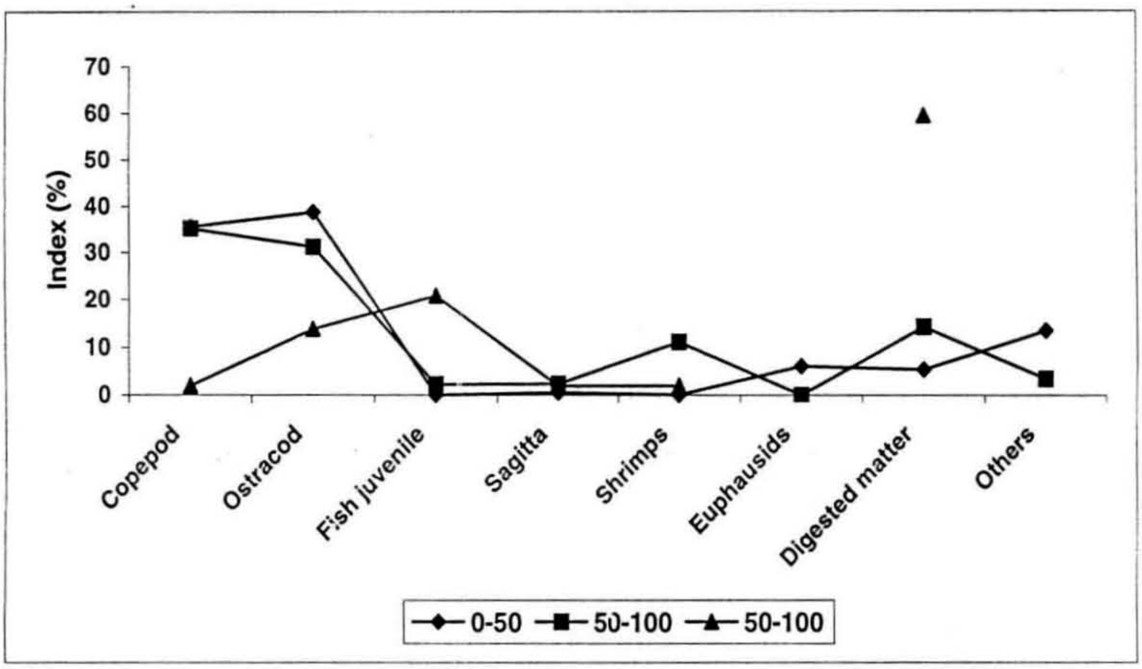


Figure 5.16 Temporal Variation in Food Contents in *V. lucetia*

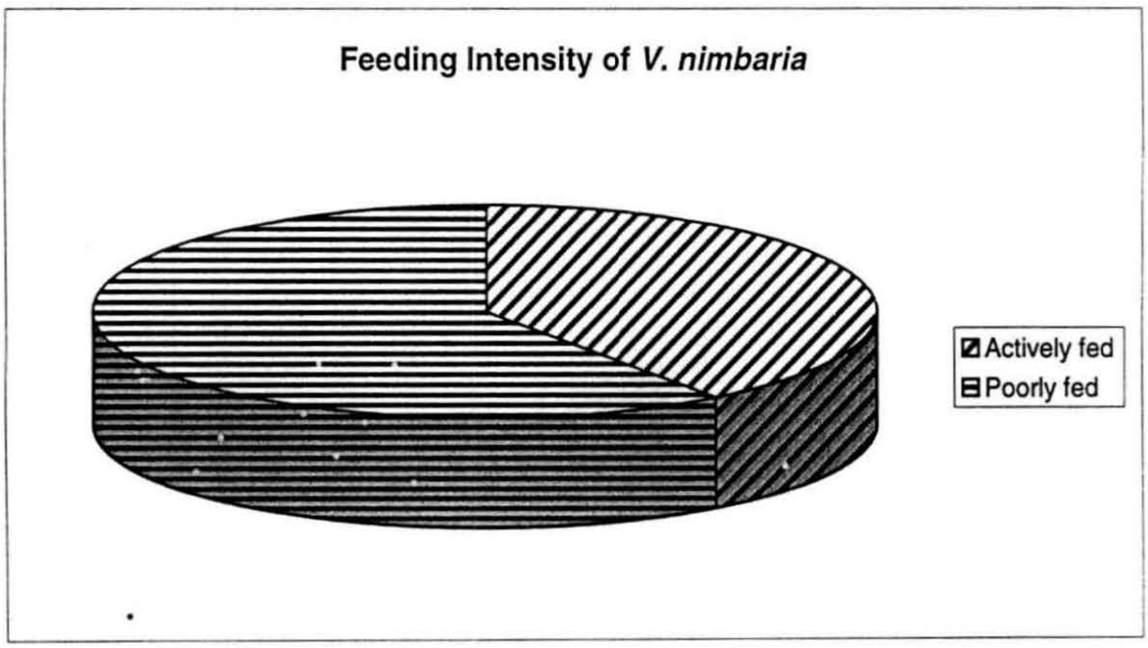


Figure 5.17 Feeding Intensity of *V. nimbaria*

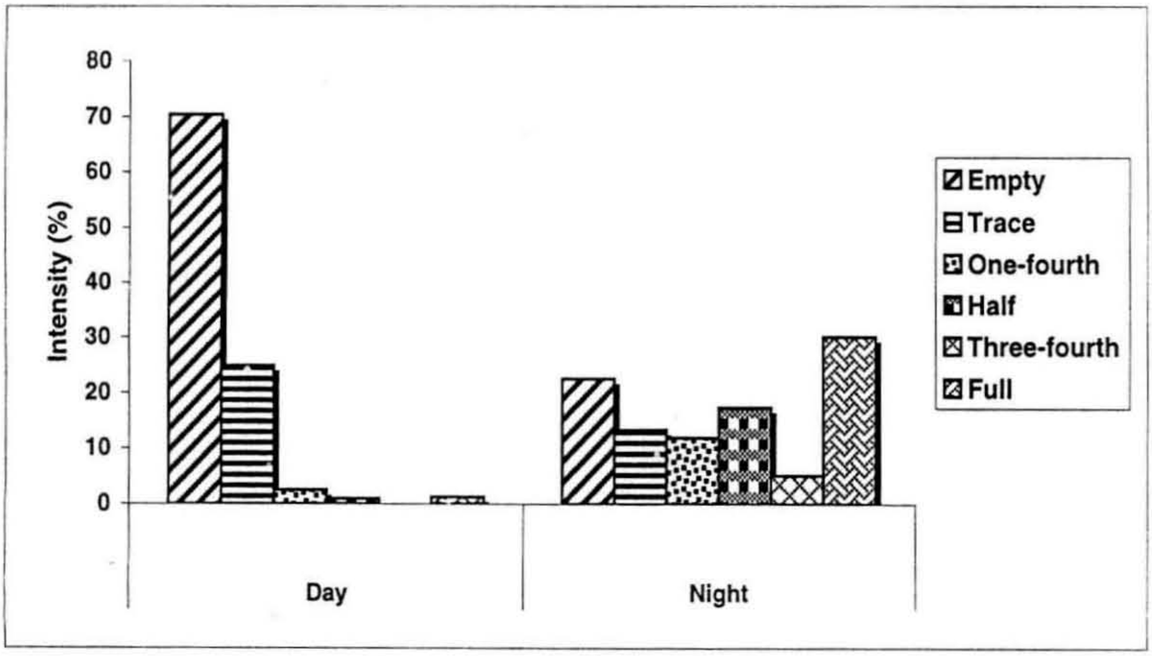


Figure 5.18 Diurnal Variation in Feeding Intensity in *V. nimbaria*

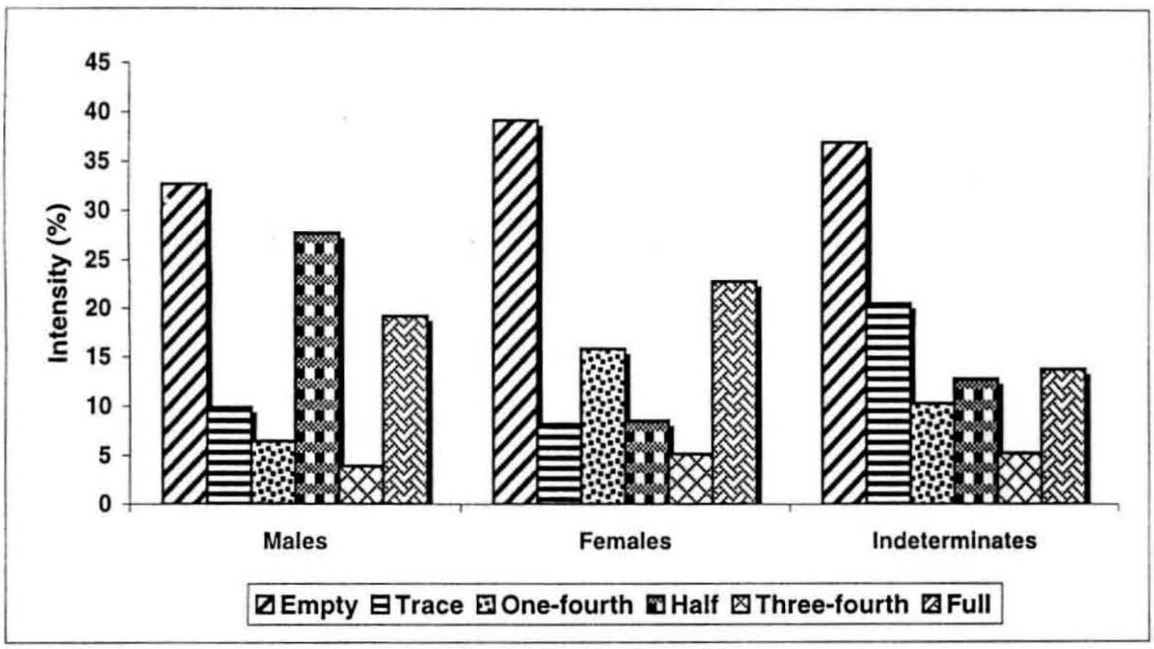


Figure 5.19 Variation in sexes in Feeding Intensity in *V. nimbaria*

5.3.3.2 Feeding intensity in relation to Males, Females and Indeterminates:

The feeding intensity in males was the highest at 51%, while in females and juveniles was found to be lower at 37% and 32% respectively. (Figure. 5.19). The empty stomachs recorded for males, females and juveniles showed little variation at 32%, 39%, 37% respectively. The poorly fed males,females and indeterminates was recorded at 49%, 63%,and 68% respectively.

5.3.3.3 Feeding intensity in relation to length groups:

In lengthgroups of 40-49mm the feeding intensity was the maximum at 50.01 %. In length groups of 30-39 mm the feeding intensity was 36.7% . In length groups of 20-29 mm, it was found to be 34.69% and that of 10-19 mm was the least at 33.2%. (Figure. 5.20). The empty stomachs recorded for various length groups was recorded at 67% (10-19mm),65% (20-29mm),63%(30-39mm) and 50.21%(40-49mm). The poorly fed fishes recorded was 67%(10-19mm), 65% (20-29mm), 63%(30-39mm), 50%(40-49mm)

5.3.3.4 Feeding intensity spatially :

The feeding intensity was the highest at Lat19°N (91.95%) followed by a high feeding intensity at Lat.13°N(88.61). 100% empty stomachs was observed at Latitudes 6°Nand Lat.16°N.. Very poor feeding was recorded at Latitudes 7°N,and 14°N (Figure 5.21).

5.3.3.5 Feeding intensity month wise:

May, July, November and December recorded high feeding activity.The feeding intensity recorded at various months is as follows

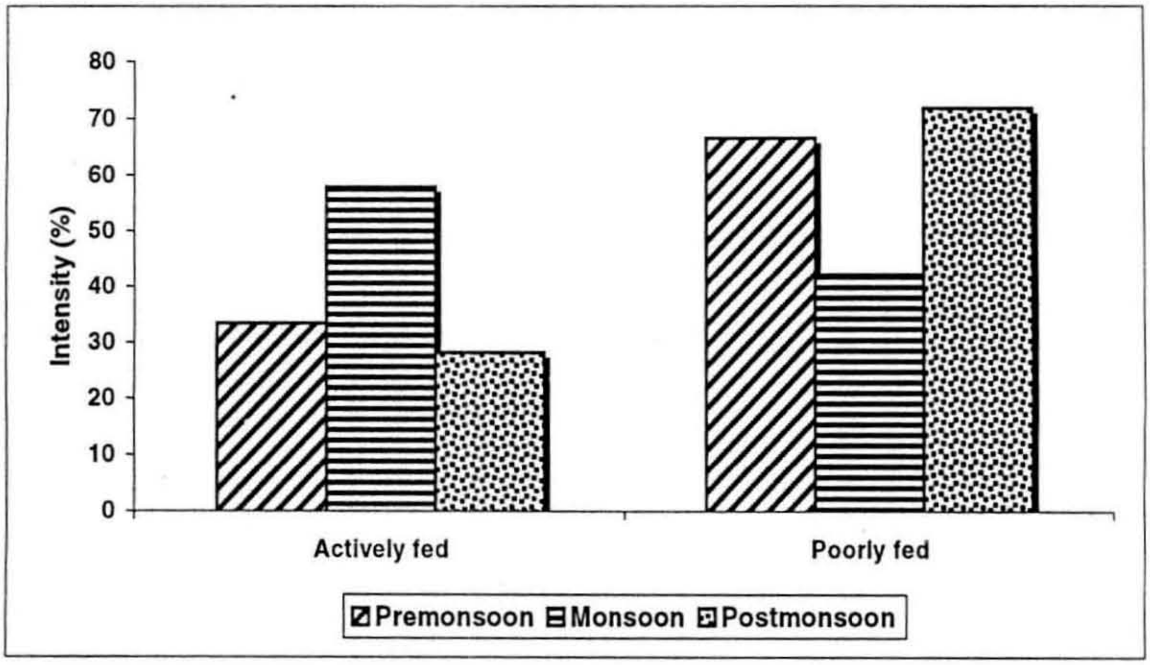


Figure 5.20 Variation in length groups in Feeding Intensity in *V. nimbaria*

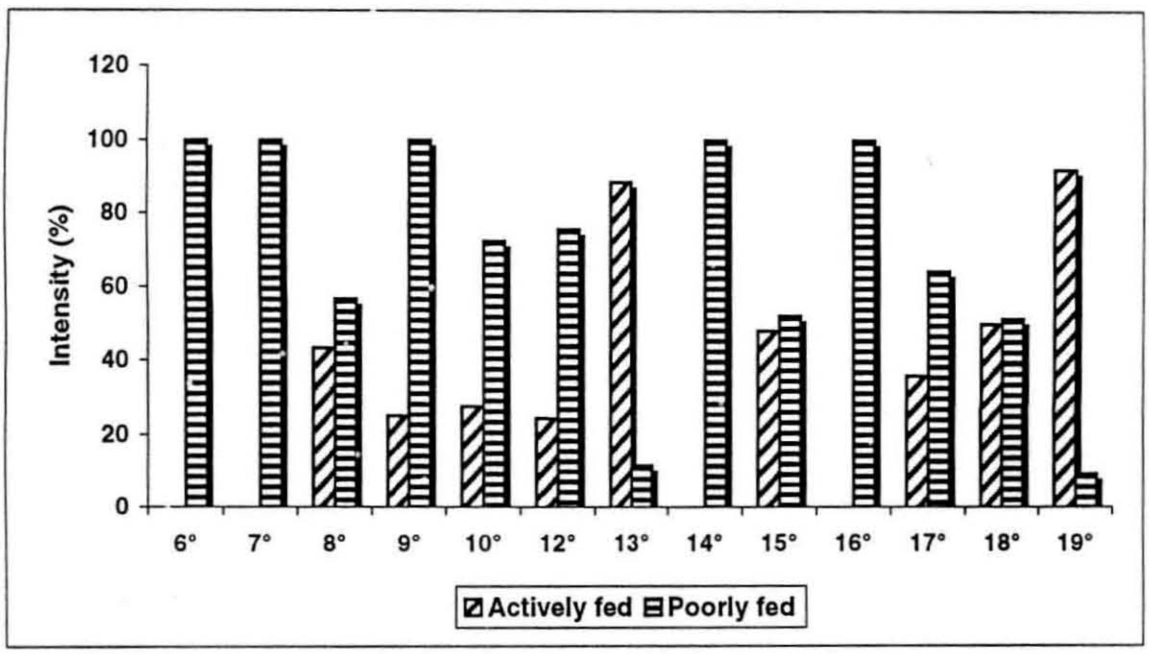


Figure 5.21 Spatial Variation in Feeding Intensity in *V. nimbaria*

April: The feeding intensity was only 2.78% .Thus feeding took place the least in this month.

May : The feeding intensity was 51.52% and poorly fed were 48.46%. Empty stomachs were seen at 34.58%.

June: The feeding intensity was nill. All were empty stomachs were observed.

July: The feeding intensity was calculated as 47.78%. Poorly fed ones were 52.22%. The empty stomachs were seen at 27.78%.

October: The feeding intensity was seen to be 18.6%, and poorly fed ones were 81.42%. 25.94% were found with empty stomachs.

November: The feeding intensity was found to be 79.32% and 20.27% were poorly fed ones. 3.79% were found with empty stomachs.

December: 75.55% were actively fed while 44.44% were found to be poorly fed. 7.78% were empty stomachs.(Figure 5.22).

5.3.3.6 Feeding intensity season-wise:

The feeding intensity was the highest in monsoon at 57.93%. The poorly fed ones were 42.06%. In pre-monsoon the feeding intensity was 33.41% and 66.57% were poorly fed ones. In post-monsoon the feeding intensity was 28.23% and 71.76 % were poorly fed ones. (Figure 5.23).

5.3.3.7 Feeding intensity bathymetrically:

The feeding activity was found to take place in surface water from 0-100m, at depths greater than 100m feeding activity recorded was low. At 0-50m the feeding intensity was 34.37% and 65.63% were poorly fed. At 50-100m 73.84% were actively fed and 26.16 were poorly fed. At 100-300m the actively fed ones were 3.18% and poorly fed ones were 96.82%. At below 300m , 12.87% were actively fed and 87.13% were poorly fed. (Figure. 5.24a).

The feeding intensity was found to be high at station depths from 0-200m.station depths. (Figure 5.24 c)

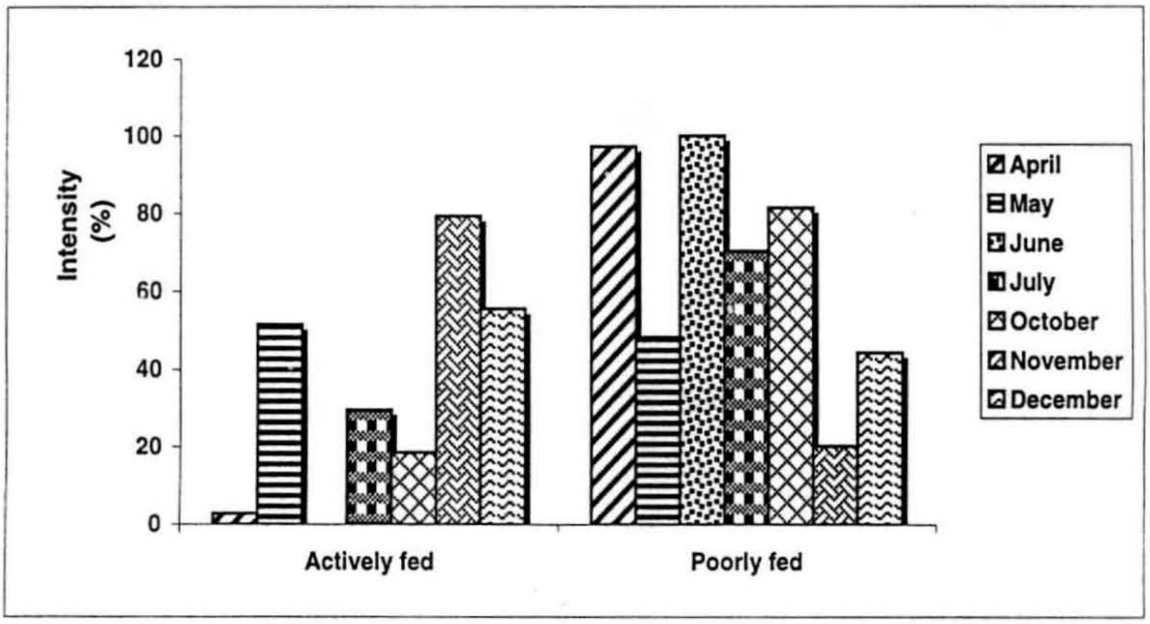


Figure 5 22 Monthly Variation in Feeding Intensity in *V. nimbaria*

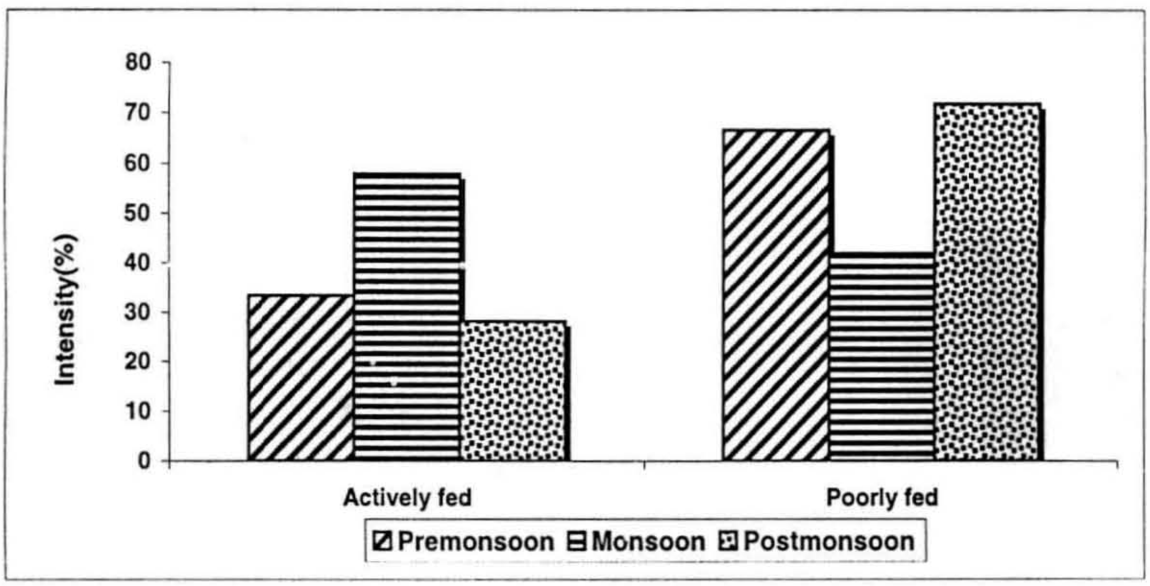


Figure 5.23 Feeding intensity by *V. nimbaria*

5.3.3.7a Diurnal variation in the feeding intensity vertically

During day at 100-300m the feeding intensity was 6.35% at other depths during day all were poorly fed, while at night a high feeding intensity was recorde at 0-50m (68.72%) and at 50-100m (54.15%) were actively fed .At depths greater than 100m feeding intensity was low, i.e., 100-300m (Nill feeding) and depths greater than 300m (74.27%). (Figure. 5.24b).

5.3.3.7b Diurnal variation in the feeding intensity horizontally

During night there was a high feeing intensity at 0-200m and during day the feeding intensity was high from depths 200-1000m. (Figure 5.24d)

5.3.3.8 Feeding intensity hourly wise

The feeding intensity was found to be high during evening and mid-night hours. During early morning hours and during the day the feeding intensity was seen to be very low. The feeding intensity at various hours is shown graphically in Figure. 5.25. The feeding intensity at various hours is as follows:

At 4.00-4.30 hrs 40.47 % were actively fed and 59.52% were poorly fed. At 5.00-6.00 hrs 36.82% were actively fed and 62.5% were poorly fed. From 6.00-9.00 hrs 100% were poorly fed. At 9.00-10.00 hrs 44.45% were actively fed and 55.55% were poorly fed. At 13.30- 15.00 hrs 100% were poorly fed . At 1900-19.30 hrs 30% were actively fed and 69.33% were poorly fed. At 20.00-21.00 hrs 60.87 % were actively fed and 38.95 % were poorly fed. At 21.00-22.00 hrs 78.65% were actively fed and 21.22% were poorly fed and 3% were empty stomachs.At 1.00-1.30 hrs 50% were actively fed and 50% were poorly fed.

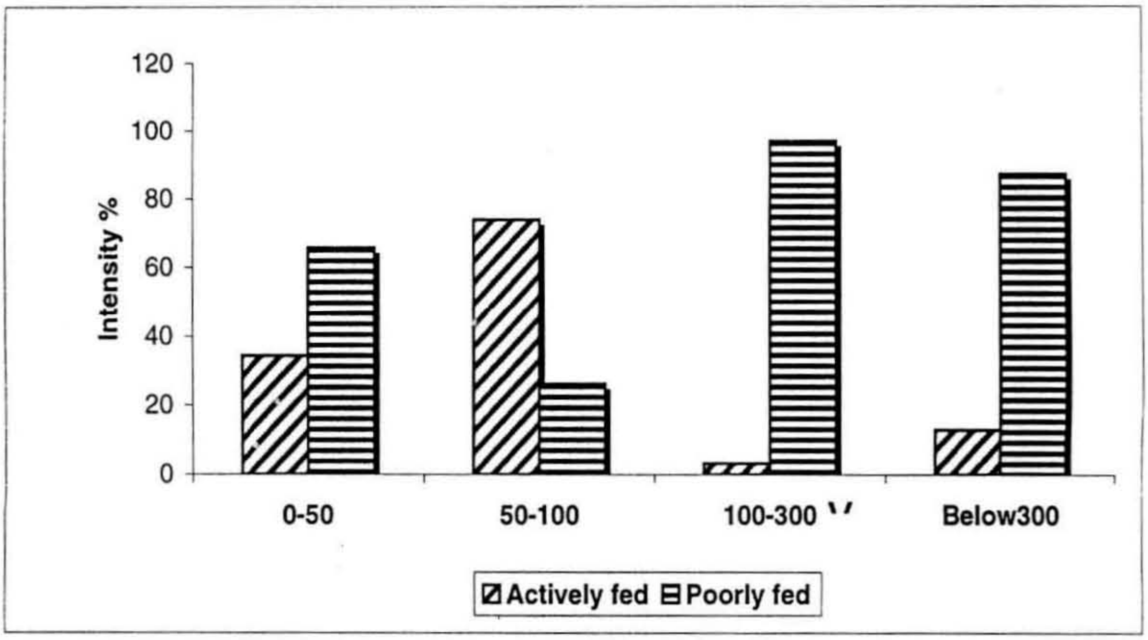


Figure 5.24 Vertical Feeding Intensity in *V. nimbaria*

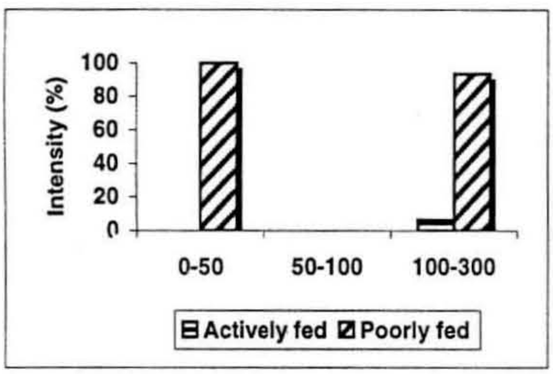


Figure 5.24a Vertical feeding intensity - Day

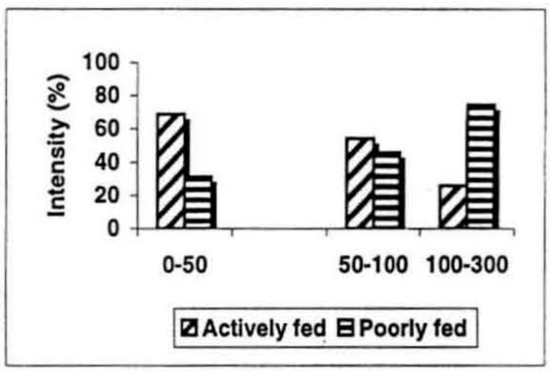


Figure 5.24b Vertical feeding intensity - Night

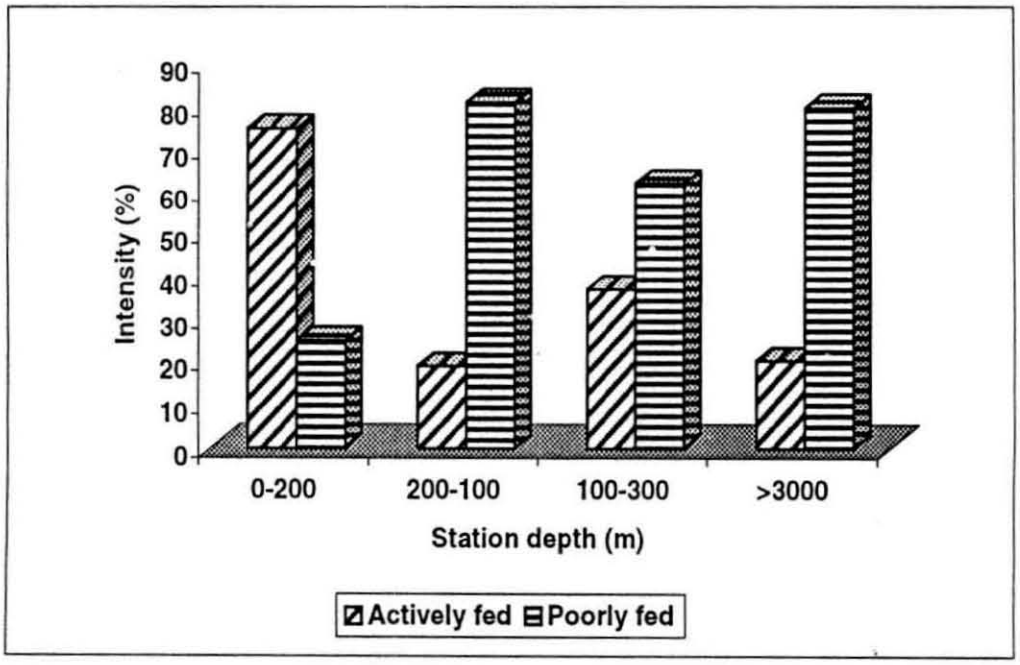


Figure 5.24c Horizontal feeding intensity in *V. nimbaria*

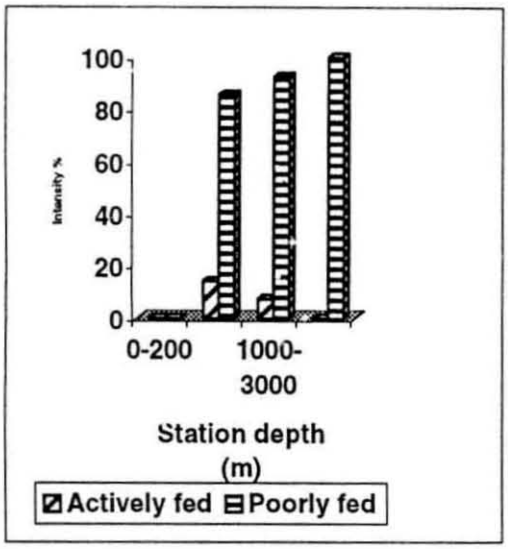


Figure 5.24d Horizontal feeding intensity in *V. nimbaria* (day)

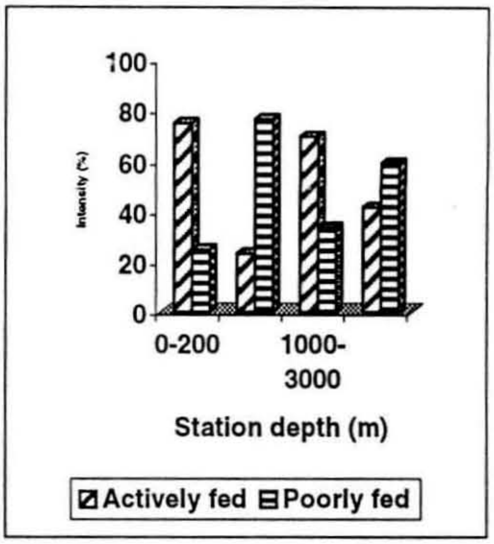


Figure 5.24e Horizontal feeding intensity in *V. nimbaria* (night)

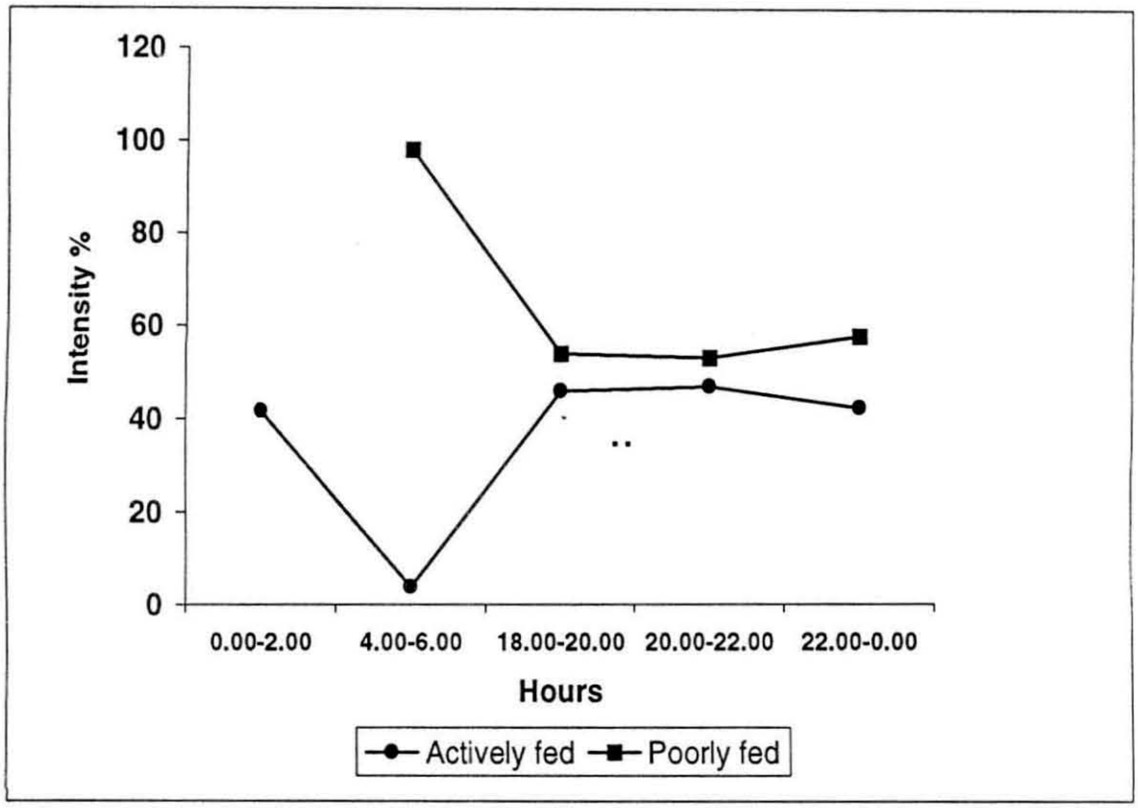


Figure 5.25 Temporal Feeding Intensity in *V. nimbaria*

5.3.4 Feeding intensity in *V. lucetia*

The feeding intensity in *V.lucetia* was found to be 43.84% . 56.14 %were poorly fed. The empty stomach recorded were 18%, trace was 20%, one fourth full were 18%, half full stomachs were 7%, three fourth full were 7% and those with full were 33%.(Figure. 5.26).

5.3.4.1 Feeding intensity in Males, Females and Indeterminates

The feeding intensity in males were highest at 57%, for females and indeterminates were recorded at 32% and 42% respectively. Full stomachs for males, females and indeterminates were recorded at 40%, 29% and 42% respectively. The poorly fed fishes for males were 43%, females 67% and indeterminates 58%. The full stomachs for males, females and indeterminates were recorded at 40%, 29% and 42% respectively. (Figure.5.27)

5.3.4.2 Feeding intensity length wise:

In lengthgroups of 20-29mm the feeding intensity was the maximum at 52.49 %. In length groups of 30-39mm the feeding intensity was 38.6% In length groups of 40-49 mm it was found to be 38.6% and that of 10-19mm was 39.77%. (Figure 5.28) No empty stomachs were recorded in length groups of 10-19mm. In the other length groups empty stomachs recorded were as follows ; 20-29mm (17%);30-39mm(19%);40-49mm(61%).

5.3.4.3 Feeding intensity spatially:

The highest feeding intensity was recorded at Lat.7°N and Lat.16°N (75% and 72.21%). The lowest feeding intensity was recorded at Lat.8°N(21.43%). (Figure. 5.29).

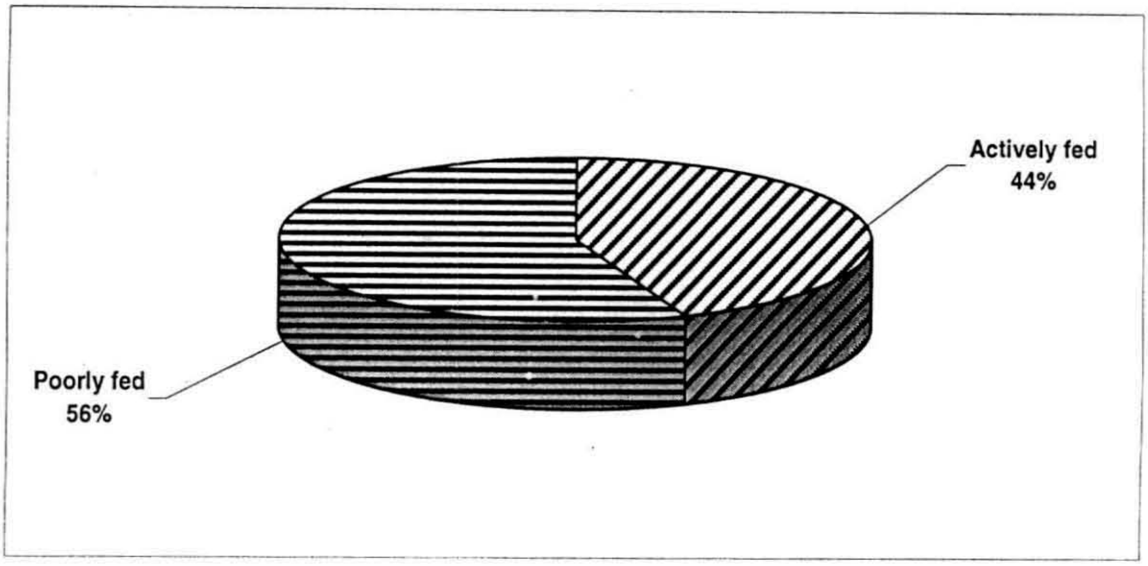


Figure 5.26 Feeding intensity in *V. lucetia*

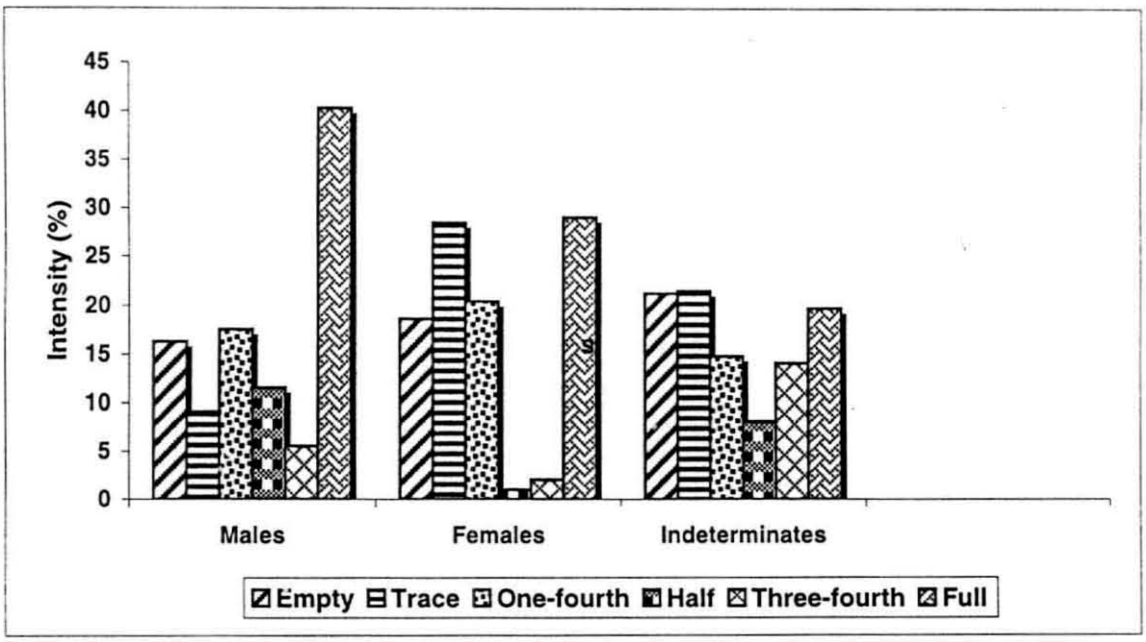


Figure 5.27 Feeding intensity of *V. lucetia* - Sex variation

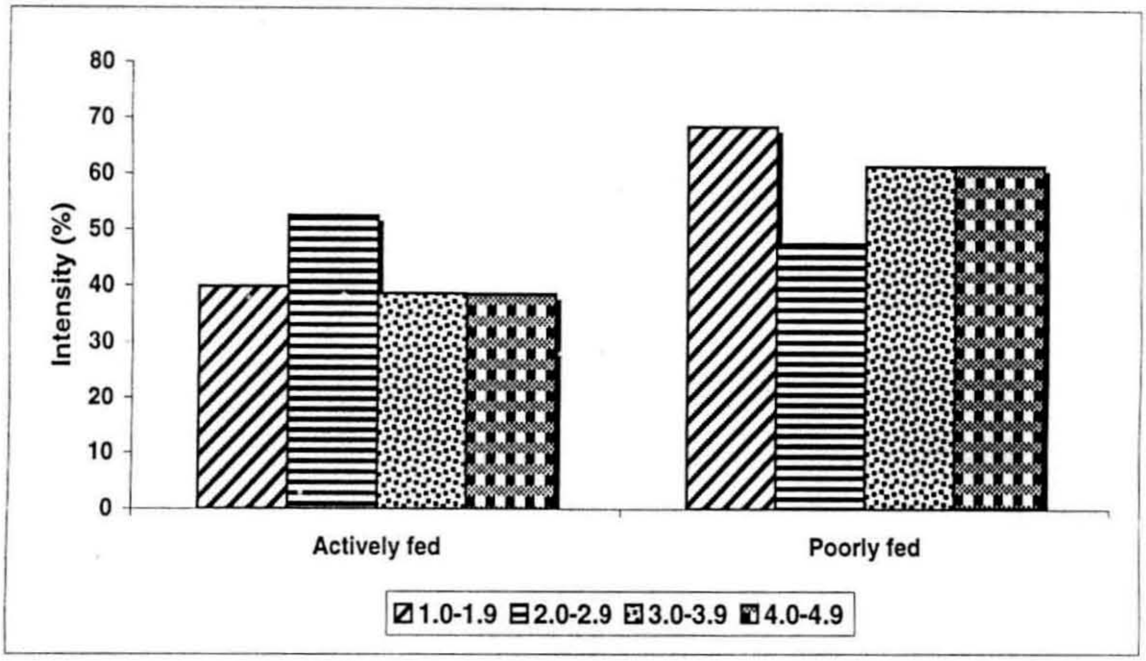


Figure 5.28 Feeding intensity length wise *V. lucetia*

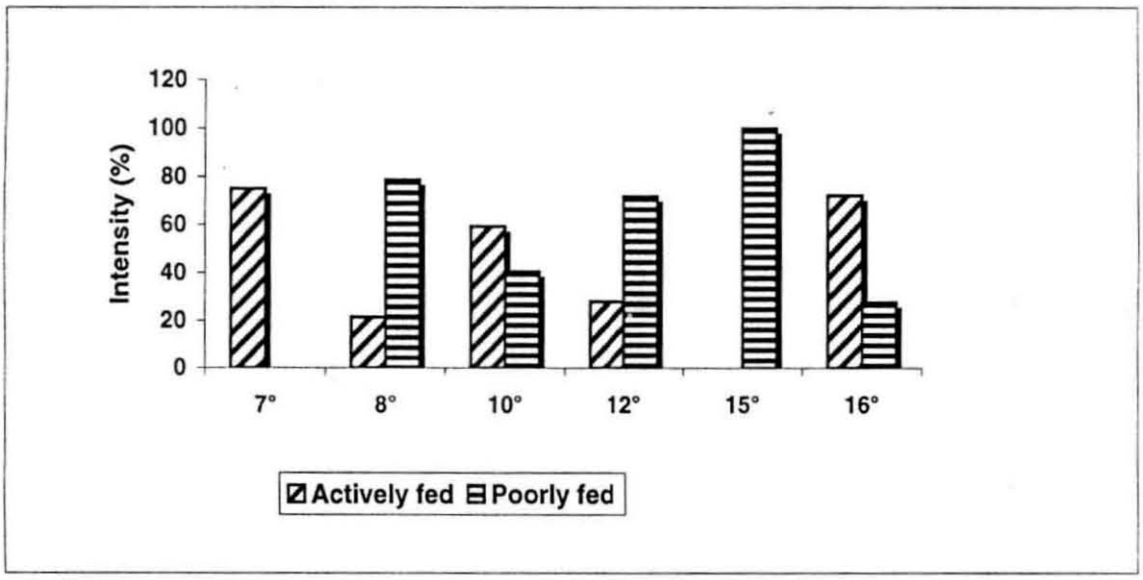


Figure 5.29 Feeding intensity at various latitudes *V. lucetia*

5.3.4.4 Feeding intensity monthly:

Feeding was high in all the months of survey except in October.

May: The feeding intensity was 43.72% and 56.22% were poorly fed ones. No empty stomachs seen.

July: The feeding intensity was 90.9% and 9.09% were poorly fed ones.No empty stomachs seen

October: The feeding intensity was Nill and 100% were poorly fed ones.80.59% were empty stomachs.

November: The feeding intensity was 56.98 %and 43.02 %were poorly fed ones.17.30% empty stomachs seen

December: The feeding intensity was 44.38% and 55.62% were poorly fed ones.No empty stomachs seen. (Figure. 5.30).

5.3.4.5 Feeding intensity season wise by *V.lucetia*:

Premonsoon : The feeding intensity was 42.78 %and 57.22% were poorly fed ones.No empty stomachs seen

Monsoon: The feeding intensity was 90.9% and 9.09% were poorly fed ones.No empty stomachs seen

Post-monsoon: The feeding intensity was 33.79% and 66.21% were poorly fed ones.32.63% were empty stomachs .(Figure. 5.31).

5.3.4.6 Feeding intensity bathymetrically :

The feeding activity at 0-50m was 55.25%, and at 50-100m was 51.66%.This showed that from 0-100m vertical depths the feeding intensity was high. (Figure. 5.32a) At horizontal depths (Figure 5.32b) i.e., at station depths of 200-1000m the feeding intensity was seen to be high.

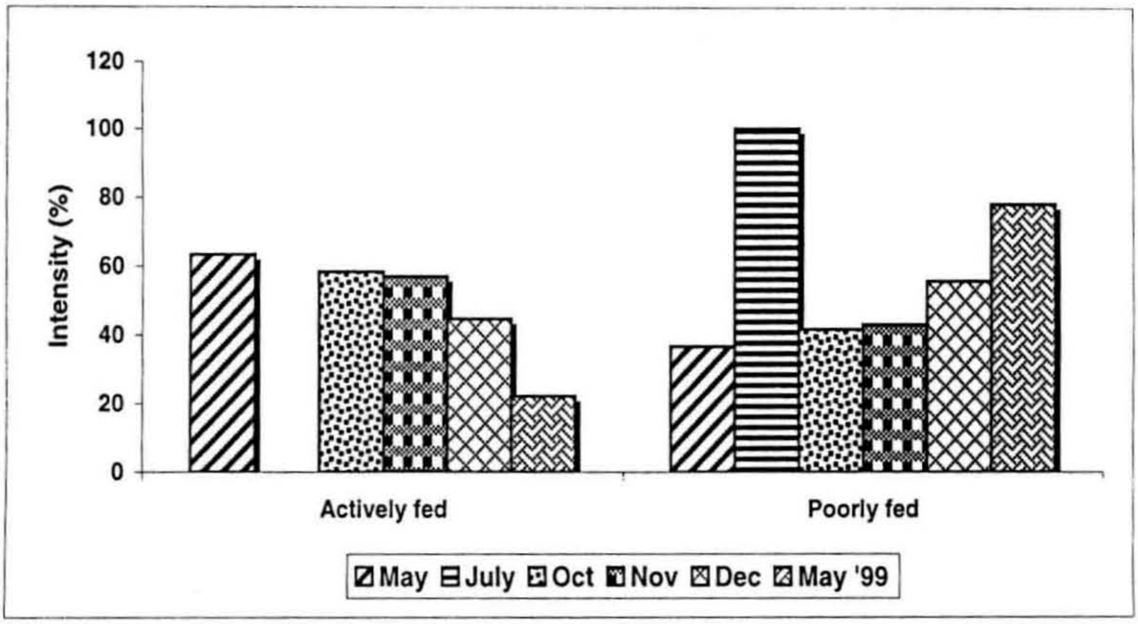


Figure 5.30 Monthly feeding intensity in *V.lucetia*

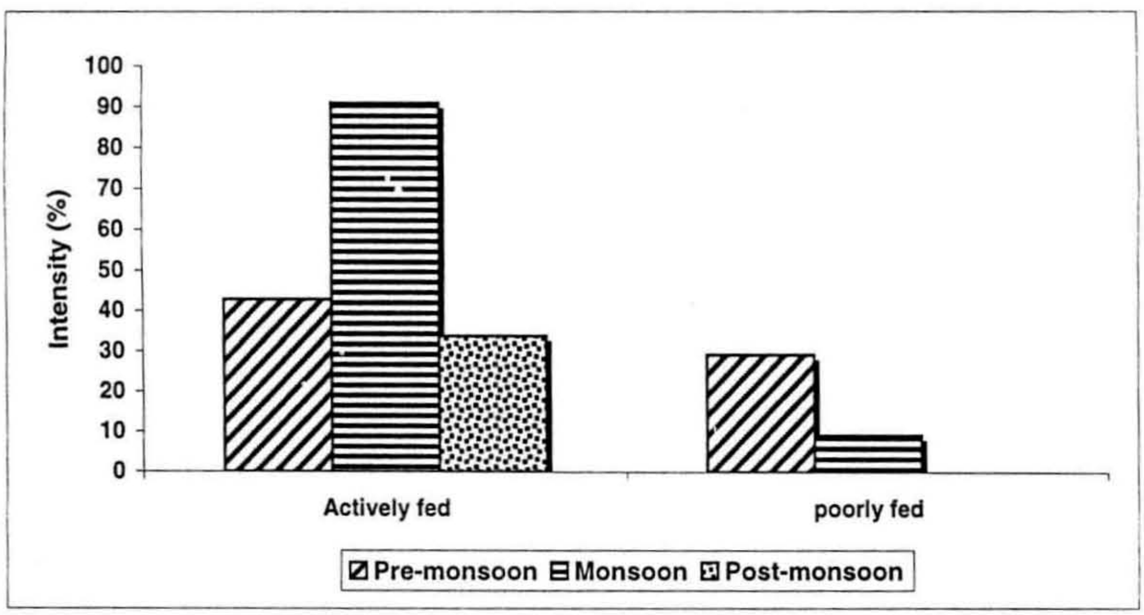


Figure 5.31 Feeding intensity in seasons in *V. lucetia*

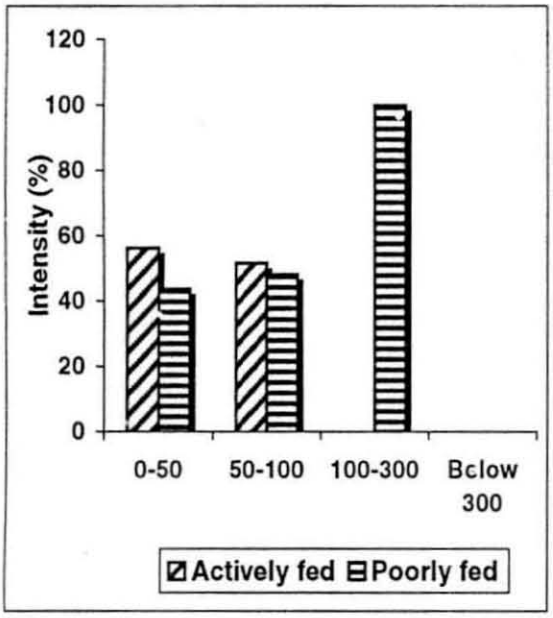


Figure 5.32a Vertical feeding intensity in *V. lucetia*

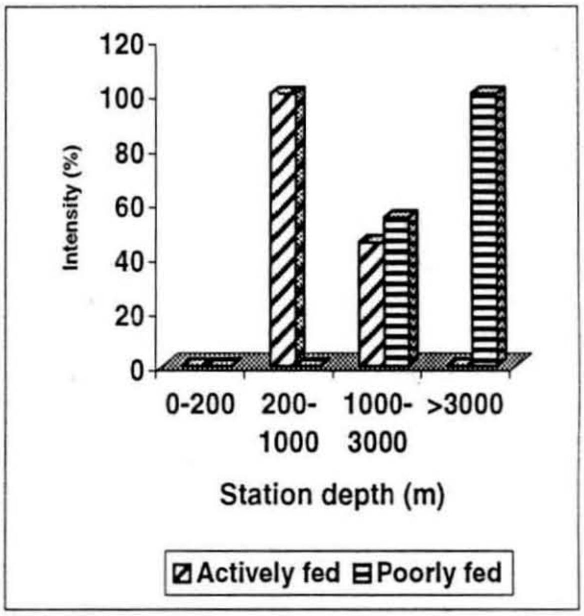


Figure 5.32b Horizontal feeding intensity in *V. lucetia*

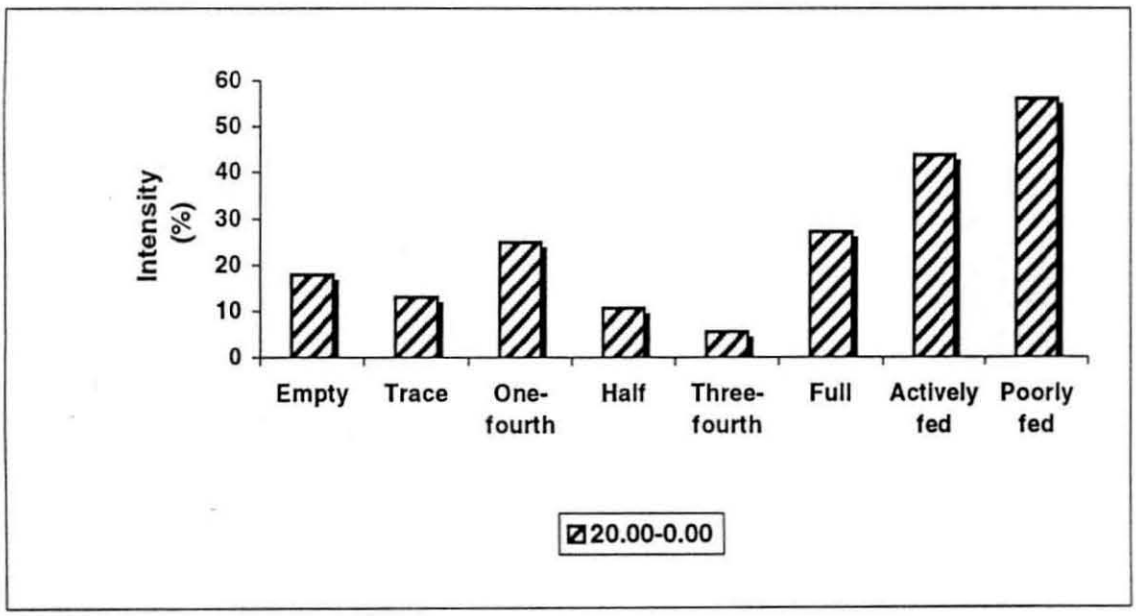


Figure 5.33 Temporal feeding intensity of *V. lucetia*

5.3.4.7 Temporal feeding intensity:

At 20.00-0.00 hrs the feeding intensity was 43.84% and 56.14% were poorly fed. (Figure. 5.33).

5.4 Discussion:

Information on feeding of species of the genus *Vinciguerria* in the Pacific and the Indian oceans has been reported in several publications. (Legand and Rivaton, 1969, Legand *et al.,* 1972, Ozawa *et al.,* 1977, Clark 1978, Kawamura and Hamaoka 1982, Kalnina and Shevchenko, 1984, Menon *et al.,* 1996). It was reported that Vinciguerria feeds on small and medium sized copepods found in the epipelagic zone (0-200m) Layers.

The present study showed that V. *nimbaria* and *V. lucetia* are typical planktophage feeding on copepods , ostracods, shrimps, euphausids, pteropds, amphipods, fish eggs and unidentified zooplankton miscellaneous. The present findings agree with that of Shevchenko (1986) that Vinciguerria is a planktophage but shows that both copepods and ostracods predominated the diet. Amphipods pteropods were seen in still smaller numbers. Shrimps formed a significant proportion to the diet. Digested matter is included here as it gives an idea of the time of feeding. It includes fully digested matter and detritus.

The food composition of both the species remained the same. The work done by Legand *et al.,* (1972) in the equatorial and the Southern regions of the Central and Western Pacific Ocean showed that copepod constituted 83% of the food. The other components such as shrimps, euphausids fish juveniles pteropods and amphipods were represented in smaller numbers. Digested matter, which constituted partially digested ostracods, copepods shrimps represented preceded feeding activity. According to Kawamura and Hamaoka (1982)copepods were found to be the most important in the diet of the species. The present work also agrees with the work done by Menon *et al.,* 1996.

The present findings relating to the food items of *V. lucetia* agrees with the work done by Lipskaya (1985)on the feeding of larvae and fry of *V. lucetia* (Garman,1899) (Gonostomatidae) in the South East Pacific. He reported that the fry of panama light fish (*V. Lucetia*) fed actively on zooplankton (Copepods and *Oncaea species* accounted for 90% and 50% of the diet respectively.) The feeding of the light fish fry was found to be typical of most pelagic species.

Seasonal and month-wise variations in the food components of *Vinciguerria* can be attributed to the changes in the abundance of food organisms due to environmental factors affecting availability of food. (Mathew *et al.*, 1990) The month wise feeding of *V. nimbaria* and *V. lucetia* was found to differ. The ostracods were the least in the month of May (pre-monsoon). The monsoon and post monsoon period indices in *V. nimbaria* were higher. In *V. lucetia* ostracods were seen in almost all seasons. Mathew *et al.*, (1996) in their studies on the ostracods in the west coast of India showed high concentration of these organisims in the monsoon season. This was due to the swarming nature of the ostracods. The minimum number was obseved during pre-monsoon period. This agrees with the present findings and that of Menon *et al.*, (1990).

Copepods were found at high indices in premonsoon and postmonsoon and found at low indices in monsoon in *V. nimbaria* whereas in *V. lucetia* copepods were found at high indices in all the seasons. The high indices of copepods indicate the availability of copepods in that area.. Mathew *et al* .,(1990)found that the concentration of copepod was relatively high during the monsoon season in the area off south west coast of India while in the off-shore areas their distribution was patchy. During premonsoon and post monsoon some of the specimens had their stomachs full with copepods alone. Pelagic shrimps form important forage for a number of fish species inhabiting the shelf waters which support commercial fishes. Natraj, (1947);Chacko, (1949), Venktraraman ,(1960), Suseelan and Nair (1969) have shown that the link between the zooplankton and large animals of the higher trophic levels in the food chain which transport organic matter produced in the upper layers to the lower layers of the sea through vertical migrations. In *V. nimbaria* high indices of shrimps were seen in monsoon and premonsoon, In *V.lucetia* the shrimps were at high indices in pre-monsoon and at lesser indices in monsoon and postmonsoon. In monsoon *V. nimbaria* preferred shrimps due to the less number of copepods while in *V. lucetia* copepods were more and the shrimps were at lower indices. These findings agree with that of Mathew *et al.*, (1996) and Menon (1990).

The monsoon season with recording 46% of euphausids was more productive, the pre-monsoon and post-monsoon sharing almost the same quantity equaled to around 27%. Agreeing with the above, in the present finding there was a small amount of euphausids in monsoon while denser quantity in pre and post-monsoon. In *V. lucetia* the indices was much higher in monsoon.

Digested matter was seen in all the three seasons and consisted of partially digested or fully digested matter. In *V. nimbaria* digested matter was present in higher quantites than that in *V. lucetia* which indicated preceeded feeding activity.

The present study agrees with Vinegradovs (1962) hypothesis, which postulates that the active vertical transport of organic matter is by migratory and feeding behavior of mesopelagic organisms. Vertical migration in midwater fishes has for a long time been thought to be closely concerned with feeding. Marshall (1960) stated that there could be little doubt that the daily climb towards the surface by fish is a feeding migration. He opined that during day they feed on whatever avaiable, but have a proper meal at night. This has been conformed by many subsequent studies.

The most common diel vertical migration behavior observed in zooplankton is to ascend to the surface layers at dusk and descend to the deeper layers at dawn. (Cushing 1951). The fish *V.nimbaria,* from the family Photicthyidae not exceeding 5cm length, is considered to belong to the mesopelagic fauna that perform dial migration. At the end of night the *Vinciguerria* species go up to the surface very rapidly ,100-150m to the surface where they scatter and then at the morning 6.00am form schools which go down towards the thermocline during the morning and stay there the rest of the time. Agrees with the finding of Timonin (1971). Marshall

(1960) stated that there can be little doubt that the daily climb towards the surface by fish is a feeding migration.

At night a increase in the amount of copepods, ostracods were seen while in day shrimps and digested matter dominated. Studies by Mathew *et al.*, (1990) of the cruises of the **FORV *Sagar Sampada*** in the EEZ of India showed that night catches showed recorded more ostracods showing pronounced diurnal vertical migration. Studies conducted by Silas (1972) on the DSL in the Lakshadweep sea showed fluctuations in the abundance of ostracods in the day and night collection. Habeland and Strata (1973) showed dial variation in copepod distribution. Studies by Mathew and Natrajan (1989) showed that there was pronounced day and night difference in the abundance of euphausids. They concluded that large amounts of euphausids were found in the night samples. Distinct diurnal migration of pelagic shrimps is evident from the day and night variation in the catch of the IKMT hauls. Species at depth range of 800-1500m, however, perform only limited upward migration. During day time in the absence of zooplankton they fed on shrimps.

Amphipods, pteropods showed a very poor representation in the DSL . Whenever the availability of food items is low the fish showed less preference to the items. In the present study it is seen that no samples of the fishes were taken in the 50-100m layers at day whereas at night these layers showed the occurrence of many mesopelagic fishes. They may be opportunistic feeders feeding on the prey when ever available.

The change in diet composition in relation to different depths were studied based on fishes collected from surface to greater than 300m. The vertical migration plays a important role in providing food for demersal and pelagic organisms. (Carlos and Jainne (1998). Jayaraman *et al.*, (1959) said 'The day and night changes in the catch rates have something to do with feeding habits of individual categories of fishes and the diurnal vertical movements of these food organisms themselves'. At 0-50m copepods and ostracods dominated. At 50-100m copepod dominated. At below 300m copepods and ostracods were seen. The organisms are found to continually change their position in the water column. At various depth the distribution of the various organisms differed. At 0.00-4.00 hrs at 0-50m copepods and ostracods dominated. Digested matter was the least indicating feeding. At 4.00-8.0-0 hrs it fed on copepods and ostracods . Digested matter was found in quantity indicating preceded feeding habit. Invariably no feeding took place from 8.00-10.00hrs. At 16.00-20.00 hrs at 50-100m the fish fed on ostracods, copepods, shrimps and digested matter which indicated that feeding had taken place recently. At 20.00-0.00hrs the fish fed on copepods, ostracods and shrimps and the minute quantities of digested matter indicated that feeding had just taken place. In *V. lucetia* at 20.00 -0.00hrs at 0-100m depth copepods and ostracods were found in the stomachs.

The present results agree with that of Menon *et al.,* 1996 who has reported on the different food items at various hours. *V nimbaria* and *V. lucetia* fed on mesozooplanktonic organisms from DSL during day. *V. nimbaria* might be in the middle of a fairly short food chain .

Phytoplankton→microzooplankton→copepods→ostracods→*Vinciguerria*→large predators like fishes and cephalopods. They ascend the water column along with the vertically moving mesozooplankton during evening and descend down by morning. The abundance of the fish and their migration might be influenced by the availability of the prey organisms. The feeding activity was high at surface layers and minimal at depth. The mesozooplankton of the DSL was supported chiefly by euphausids, decapods, fish eggs/larvae, copepods, chaetognaths, pteropods, heteropods, crustacean larvae during day time while night catches were dominated by copepods, euphausids, decapods,pteropods, larval crustacean and fishes. *V. nimbaria* and *V.lucetia* fed selectively on copepods, ostracods, shrimps, fish remains although they formed only a small fraction of the DSL plankton.

The analysis of the present data indicates that the species is a visual feeder as evidenced by their intense feeding activity during day break and dusk hrs when the DSL moves in the column descending in day break and ascending at dusk. Th poor feeding in during daytime might be due to non-availability of the prey organism in the normal depth strata of *V. nimbaria.* During day light hours the DSL mostly macrozooplanktonic layers descend far down to 400-500m or more. Moreover, at day time the DSL forms several discrete layers and occupy different depths below the predator species habitat.

The feeding of the genus *Vinciguerria* also depended on different latitudes. In Day at Lat. 8°N *V. nimbaria* feeds on shrimps and had a high amount of digested matter while in the night they fed on ostracods , fish juveniles, sagitta, shrimps, euphausids and others . The spatial concentration of pelagic copepods in the Arabian Sea and Bay of Bengal suggests the surface circulation pattern exerts more influence in their distribution and abundance than the other latitudes. Based on studies by Menon *et al* (1996) and Mathew *et al.*, (1990) it is concluded that the feeding took place based on selection and abundance. In both *V. nimbaria* and *V. lucetia* the same phenomenon is observed.

The changes in the percentage of the food items during different times, months, seasons, and spatial distribution should have been influenced by the sampling made from different depths, their spatial distribution and diurnal migration, where the relative abundance of different food organisms showed variations.

The feeding intensity at 8.00-16.00 hrs was nill as all the stomachs were empty or trace. At 16.00-0.00hrs 40.81% were full stomachs. In *V. lucetia* at 20.00 hrs 43.84 % were actively fed while 56.14 were poorly fed. 27.43% were with full stomachs and 17.92% were empty stomachs.

During pre-monsoon months the feeding intensity was 33.41% and 66.57% were poorly fed. During monsoon 57.93% were actively fed and 42.06% were poorly fed. At post-monsoon 28.23 %were actively fed and 71.76% were poorly fed. In *V. leucita* in pre-monsoon 42.78% were actively fed and 57.22% were poorly fed.

The feeding intensity was also seen to change among the sexes. In *V. nimbaria* males were 33.33% actively fed in pre-monsoon and 66.67% were poorly fed while females were 50.27% actively fed and 49.72 % poorly fed . In monsoon the feeding intensity of males was 83.32%, females 41.66%. and indeterminates was 16.66%. During post-monsoon the feeding intensity of males were 36.11% actively fed and

63.89% poorly fed, females was 18.06% actively fed and indeterminates was 30.52% actively fed. In *V.lucetia* the feeding intensity in males in Premonsoon was 47.83%, females 33.33% and in indeterminates was 50%. In monsoon the feeding intensity was 90 % in males and females. In post-monsoon the feeding intensity in males was 32.36% in females 31.25% while in indeterminates was found to be 34.43%.

The feeding intensity during night was 52.3% and 47.83% were poorly fed. The feeding intensity during day was found to be very low in both the species. The feeding intensity also differed in different length groups in both the species. In 30-39mm the feeding intensity was the highest. In *V.lucetia* the feeding intensity was the highest in 20-29mm. The food of the adults and the young ones did not show much marked difference. The younger fishes preferred small sized copepods and ostracods in comparison to the bigger sized fishes.

The quantitative variation in respect of the food items taken from different latitudes and different depths is an indication of a probable lack of diversity of fauna obviously due to the steep descent of the shelf. On comparison of the food items identified from the stomachs of the two species of *Vinciguerria* it is seen that copepods and ostracods dominated.

According to Johnson (1977) if the occurrence of a food item exceeded 25% in two or more species that inhabit the same area competition is likely to take place among them. In the present study as the major food items have exceeded more than 25% indicating a possibility for the competition of food for the two species that coexist in the Indian EEZ.

There are reports about the feeding rhythm of *Vinciguerria* (Legand *et al.*, 1972, Ozawa *et al.*, 1977, Clarke 1978). They indicated that maximum stomach filling is observed from 18 to 22 hrs.and during this time 25% of the fish have empty stomachs as compared to 50% during the day. The authors reported that digestion of food in *Vinciguerria* takes place in 4-8 hours. The short feeding period leads to the conclusion that *Vinciguerria* feeds once a day. However, Ozawa *et al.*, (1977) on the basis of analysis of day and night samples concluded that some part of the population again feeds in the morning after 9 a.m. According to Clarke (1978) *Vinciguerria* feeds most actively in the evening between 16-20 p.m. Freshly eaten food is often found upto 20 hrs. whereas after midnight till 4a.m. only digested food residues were found in the stomach.

The present results indicate that genus *Vinciguerria* feeds generally in the evening from 16.00 –22.00 hrs. The presence of full stomachs from 21.00hrs to 22.00hrs indicates peak feeding . Freshly eaten organisms appeared in the stomach of fishes taken at 19.00hrs. and 20.00hrs. and there were only 3% empty stomachs. At 19-21hrs. no digested residues seen in the stomach . The fullness indices in the fish of the same size (31-40mm) during the night (1-2 a.m.) at different depths indicate varying levels of feeding. At depths of 50-100m at 4.00-8.00 hrs 76% of the food was found digested. This leads to the conclusion that the fish stopped feeding at in the early morning hours and start their descent towards the deeper layers.

Thus in the Indian EEZ (Arabian Sea, Present results, Menon *et al.,* 1996) *Vinciguerria nimbaria* and *Viciguerria lucetia* mainly consume small and large copepods and ostracods as prey, night is the main feeding time. As regards the possibility of feeding of *Vinciguerria* at other time the present results agree with Ozawa *et al.,* (1977) that a part of the population also feeds after 9a.m.

Chapter - VI

Reproduction

6. REPRODUCTION

6.1 Introduction

Information on the reproductive biology throws light on the generative potential, recruitment and sustainability of exploitable resources. These are of great value in fishery prediction and formulating management and conservation measures. Maturation refers to cyclic morphological changes, which the male and female gonads undergo to attain full growth and ripeness. Spawning means the emission of male and female gametes from the body of the fish to the exterior where fertilization occurs. In fishery biology studies it is important to determine the cycle of maturation and depletion of gonads. The purpose of this determination could be manifold but it is basically aimed at understanding and perhaps predicting the changes, which the population as a whole undergoes during the year. (Qasim, 1972). Information on the maturation and spawning in numbers belonging to the family Photichthyidae is limited.

Works done by Maski Miya and Takahisa Nemoto ,1991 on the comparative life histories of the meso and bathypelagic fishes of the genus Cyclothone (Pisces:Gonostomatidae) in Sagami Bay, Central Japan are available. Gorbunova, 1968 worked on the structure of eggs and breeding of *V. nimbaria*. Silas and George (1969) worked on the larval and post larval development and distribution of the mesopelagic fish *V. nimbaria* off the west coast of India and the Laccadive Sea. The breeding conditions of these numerous mesopelagic fish that are important in the food chains are still poorly understood. (Gorbunova, 1982.)

V. nimbaria are numerous and widespread and populate the upper 500m layer of the Indian EEZ. The large population of this species is confirmed by the frequency with which mature individuals are encountered. Diurnal migration rhythms are seen in the vertical distribution of *V. nimbaria, which* rise above the thermocline and possibly reach the surface at night. (Gorbunova, 1982; Clark, 1978).

It is known that many mesopelagic fish display regular diurnal vertical migration, during the night. They move to the epipelagic zone and feed there more intensively. As this is a common phenomenon occurring on large scale it is clear that the migrations are of considerable significance for the energy budget of the ecosystem of the upper oceanic pelagial. To estimate this role quantitatively it is necessary to have full information on the reproduction of these fishes. The data from the Indian waters are very scarce thus the reproductive biology of the species is studied. (Andrianev, and Bekker, 1989). No sexual dimorphism is observed.

The deep-sea environment poses certain problems not encountered in shallower waters. Among them is the absence of solar light and primary organic productivity. The lack of sunlight and consequent loss of primary autotrophic production must lead to the restriction of food supply, at least in mid water and consequent reduction in the total weight of fishes can be supported by this food supply. (Zenkervich and Birstein, 1956; Marshall, 1960). Deep sea fish population is known to be sparse compared to those in upper layers and the bathypelagic fishes are in general small.

Ova diameter studies have become an integral part of fishery biological research. It is well known that in most fishes there is marked seasonal change in egg production. Clarke (1934) and Hickling and Rutenberg (1936) have shown that it is possible to determine the time of spawning and the spawning periodicity of fishes by ova diameter studies. Works done on deep sea fishes include that of Karandikar and Palekar, 1950-1952. Prabhu (1956), Dharmamba (1959) and Karkar and Bal (1960) among others have shown that this method is applicable in regard to fishes they studied.

The gonads of the females of the species examined , show portions of mature eggs or separate group of oocytes in the vitellogenesis phase thus estimation of fecundity (i.e., absolute number. of eggs spawned at one time) was possible. Because of the well known relation between the number of eggs produced and the size and weight of females , the relative fecundity (Number of eggs per body) seems a better indicator. The values of relative fecundity are found to prove their reproductive ability.

Generation of species continues by means of reproduction, which is an integral link of the life history of fish. Fishes exhibit complexity of reproductive strategies tactics and traits so as to leave some offspring for maintaining the existence of subsequent generation. The reproductive strategy relates to the general reproductive behaviour of the individuals while the reproductive tactics are the variation in the general pattern that the fish adapts in response to fluctuations of environment. The reproductive traits include aspects such as size or age at first reproduction (maturity), size or age dependent fecundity, sex ratio, nature of gametes and timing of spawning season. (Wooton, 1984). Study on these reproductive characteristics is essential in the determination of population stock size from egg numbers, periodicity of strength of brood, spawning time and place and sex composition of exploited stock.

6.2 Materials and Methods:

Fishes collected from IKMT samples were preserved at sea in 10% formalin. In the laboratory they were identified and measured to the nearest millimeter (mm) TL and weighed to the nearest gram (g) after draining for several minutes. The sex of each individual was determined by gross examination after which if the specimen was female, the ovaries were removed, blotted and weighed together to the nearest 0.1 grams. Each ovary was then examined and the stage of the eggs contained in it was determined by the following criteria based on Prabhu 1956,which are common to all the specimens examined.

Stage 1: Immature: Ovaries small and transparent. Yolk absent from oocytes. Mean ovum diameter is 0.04mm

Stage II: Developing: Ovaries slightly enlarged and translucent . Yolk present and chorion layers form around the oocytes. Mean ovum diameter: 0.12mm

Stage III: Maturing: Ovaries firm and distended. Yolk present and chorion layers fully formed around the oocytes. Eggs visible to the naked eye, opaque. Mean ovum diameter: 0.24 mm

Stage IV: Ripe: Ovaries large and distending the body wall. Eggs visible to the naked eye, Transparent, shed with or without slight pressure in the flanks. Mean ovum diameter: 0.28mm

Stage V: Spent: Ovaries shrunk, extremely flaccid larger than stage I. Yolk absent from oocytes. Mean ovum diameter is 0.12mm.

6.2.1 Ova-Diameter studies

For the purpose of studying the duration and frequency of spawning, measurements of ova diameter were recorded following the procedures described by Clarke (1934), Hickling and Rutenberg (1936), Prabhu (1956) and James (1967). A stage ocular micrometer division (md) was used to measure the diameter of the eggs. The ova were measured from the upper middle and lower portions of the ovary. The ova diameter frequencies were pooled for plotting the graph.

6.2.2 Gonadosomatic index

The gonadosomatic index (GSI) i.e. the ratio of the gonad weight and percentage of the body weight was estimated by applying the following formula:

$$GSI = \frac{\text{Wt. Of gonad}}{\text{Wt. Of fish}} * 100$$

6.2.3 Size at first maturity

For the determination of the size at first maturity the fish are measured from the tip of the snout to the distal end of the caudal peduncle (Lc) in 2mm length intervals and the gonad development stage was determined The results of the two years samples from May '98 to May' 2000 from the west coast of the Indian EEZ are presented here.

6.2.4 Fecundity

Fecundity is defined as the number of ripening eggs in the females prior to the next spawning period. Ovaries in stage IV and V only were considered. After removing the moisture from the ovaries with blotting paper they were weighed in electronic balance to the nearest 0.001g. A small portion of the ovary was separated and weighed to the nearest 0.001g. The sampled portion was placed on a micro slide and ova were teased out. All mature ova were counted and the fecundity was estimated employing the formulae:

$$F = \frac{\text{Total wt. of ovary}}{\text{Wt. of the sample.}} * \text{Number of ova in the sample}$$

The data were analysed to fit regression lines of fecundity on total length; fecundity on body weight using the least squares method .(Snedecor and Cochran, 1967)

6.3 Results

The maturity stages were recorded during the month of November and December. Figure 6.1 shows the percentage of each maturity stage of females at every month in *V.nimbaria*. The percentage of maturing female (Stage III) increased until October and November and thereafter appeared only in less numbers while spawning females (stage IV) were observed in October-November and spent females (Stage V) were most abundant in December but lower , compared to spawning females in December. Thus the main spawning period was from November to February.

The spawning period of *V. lucetia* showed that as spawning females (stage IV) were found in November and December. However most maturing females (Stage II and III) occurred between May and November and spent females between November and December which suggest that *V. lucetia* might spawn between November and December. The pooled data for genus *Vinciguerria* showed that in the months of survey fishes in stage I contributed a high percentage except in December. In November and December stage IV and stage V individuals contributed a high percentage indicating the time of spawning.

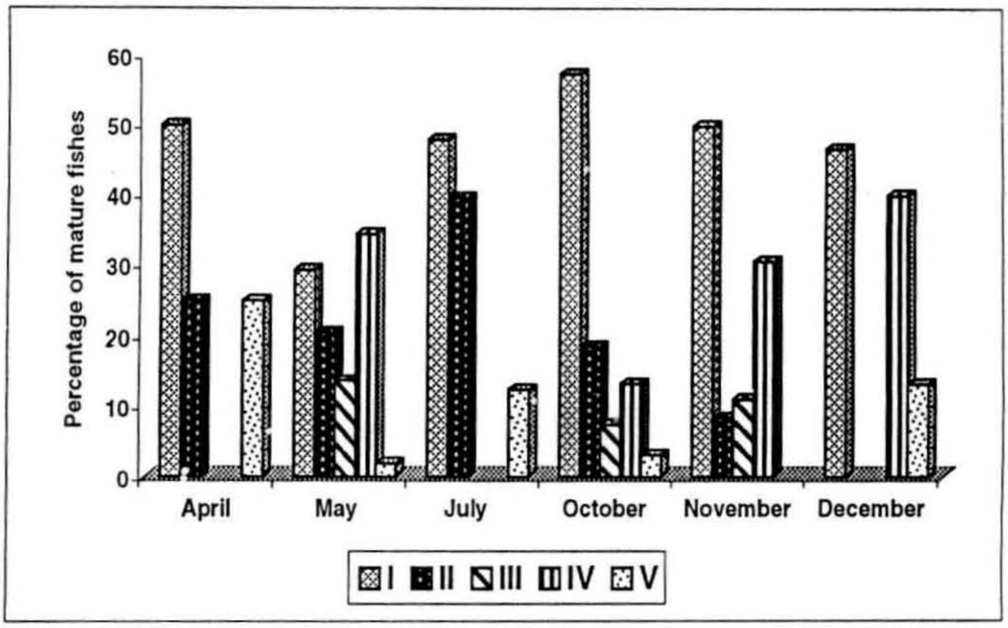


Figure 6.1 Maturity stages in relation to months in the females of *V.nimbaria*

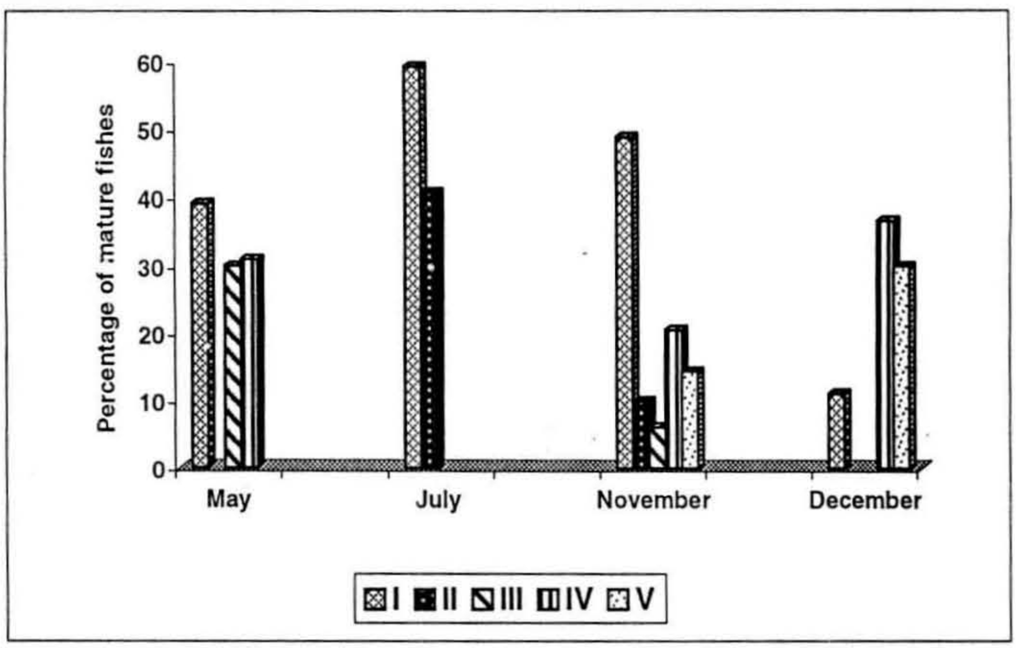


Figure 6.2 Maturity stages in relation to months in the females of *V.lucetia*

The frequency of sexes in *V. nimbaria* males were 50% and females were 40% showing a slight variation . Month wise only in May there was a significant increase in the percentage of males (89%). In *V. lucetia* the males were 49% and females were 43% again a very slight variation is seen in regard to their ratio. Monthly a significant increase was observed only in the month of December (74%). (Fig 6.3 and Fig 6.4)

The maturity stage in relation to length for females of *V. nimbaria* is as shown in Figure6.5 The maturity stage in relation to length for females of *V. lucetia* is as shown in Figure6.6.

The maturity ogive for females of *V. nimbaria* and *V. lucetia* was established using all the data from October to December being the main spawning period. The Length at maturity is estimated to be 3.0 for *V. nimbaria* and for *V. lucetia*. Immature females were easily recognized by microscopic examination and the length at which 50% of females mature were determined. (Fig 6.7 and Fig 6.8).

The ova-diameter for the different stages of the genus *Vinciguerria* (ie *V. nimbaria* and *V. lucetia*) is as shown inFigure6.9. The ova diameter studies for *V. nimbaria* showed the progressive development of the maturity stages. (Figure6.10). Month wise the following results was obtained. In April the mode at stage I was 0.12 and at stage II was 0.16. In May in stage I the mode was at 0.12, at stage II the mode was at 0.16. In October , for stage I the mode was at 0.12, for stage II the mode was at 0.16, for stage III the mode was at 0.24, for stage IV the mode was at 0.32 and for stage V the mode was at 0.08. In November, for stage I the mode was at 0.12, for stage II the mode was at 0.16, for stage III the mode was at 0.28, for stage IV the mode was at 0.24, and for stage V the mode was at 0.12. In December at stage I the mode was at 0.08, at stage IV and stage V the mode was at 0.28. The month wise changes in ova-diameter is as shown in Fig 6.11

The ova diameter for *V. lucetia* is shown in Figure 6.12. The following results were observed month-wise. (Figure 6.13 a-d) In May the mode at stage I was 0.12, at stage III the mode was at 0.24. In July at stage I the mode was 0.04 and at stage II the mode was 0.12. In December at stage I the mode was at 0.08 and at stage IV was at

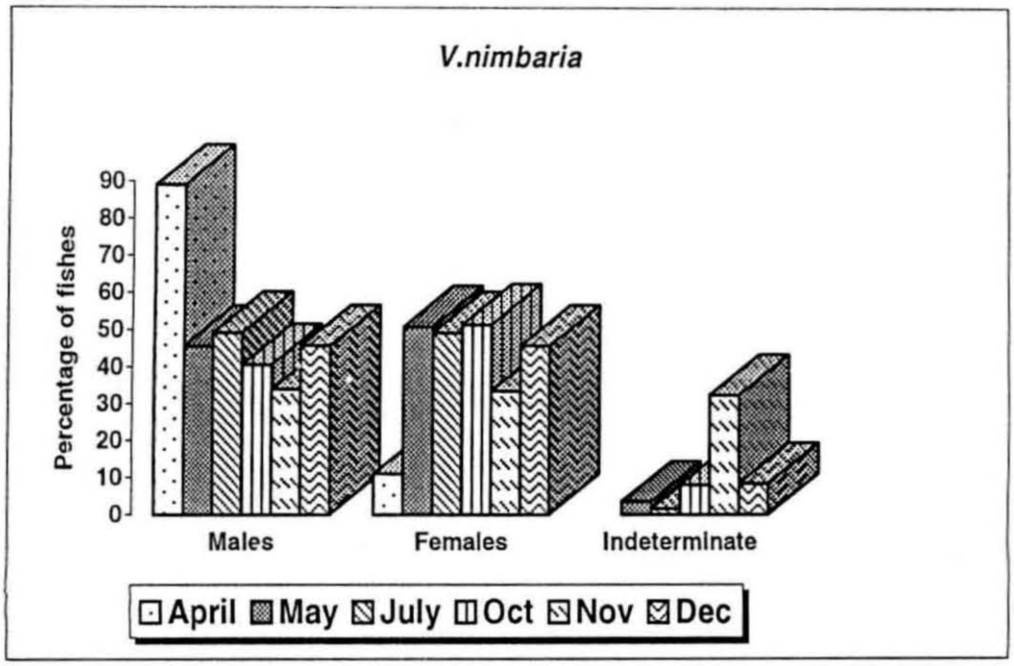


Figure 6.3 Percentage of occurrence of sexes at different months in *V. nimbaria*

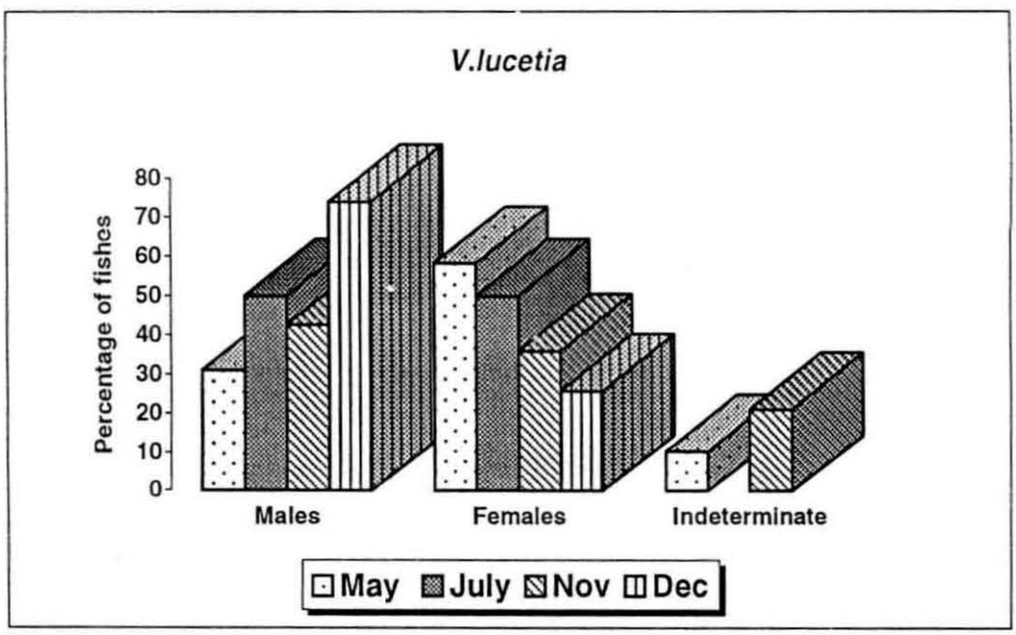


Figure 6.4 Percentage of occurrence of sexes at different months in *V. lucetia*

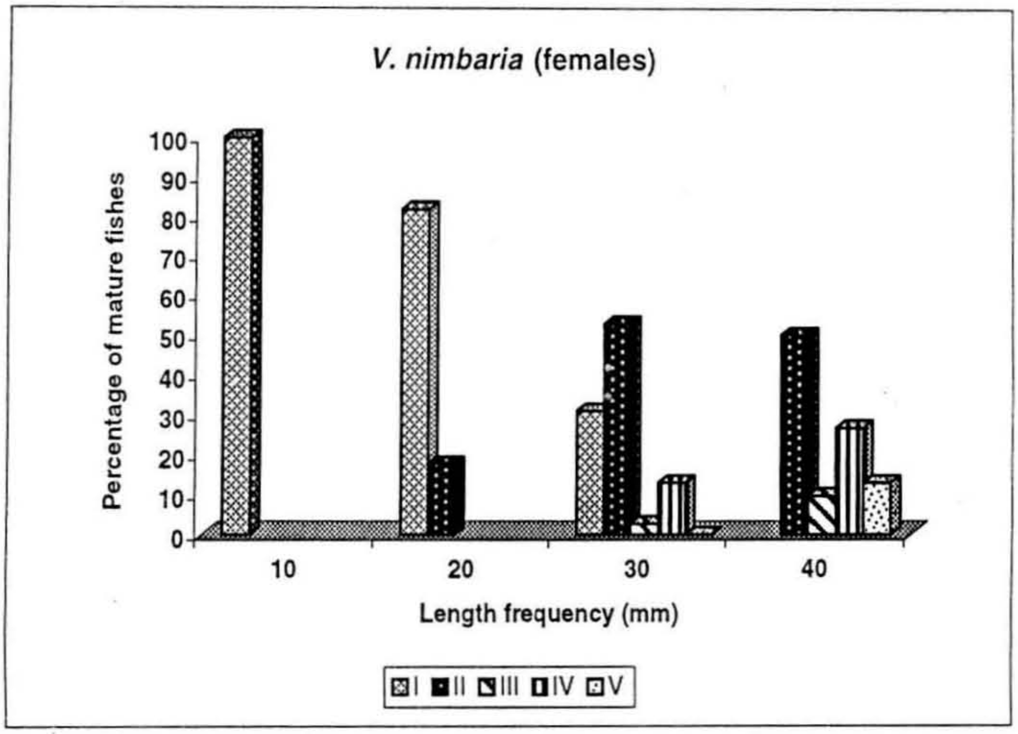


Figure 6.5 Length frequency distribution of different stages in *V. nimbaria* females

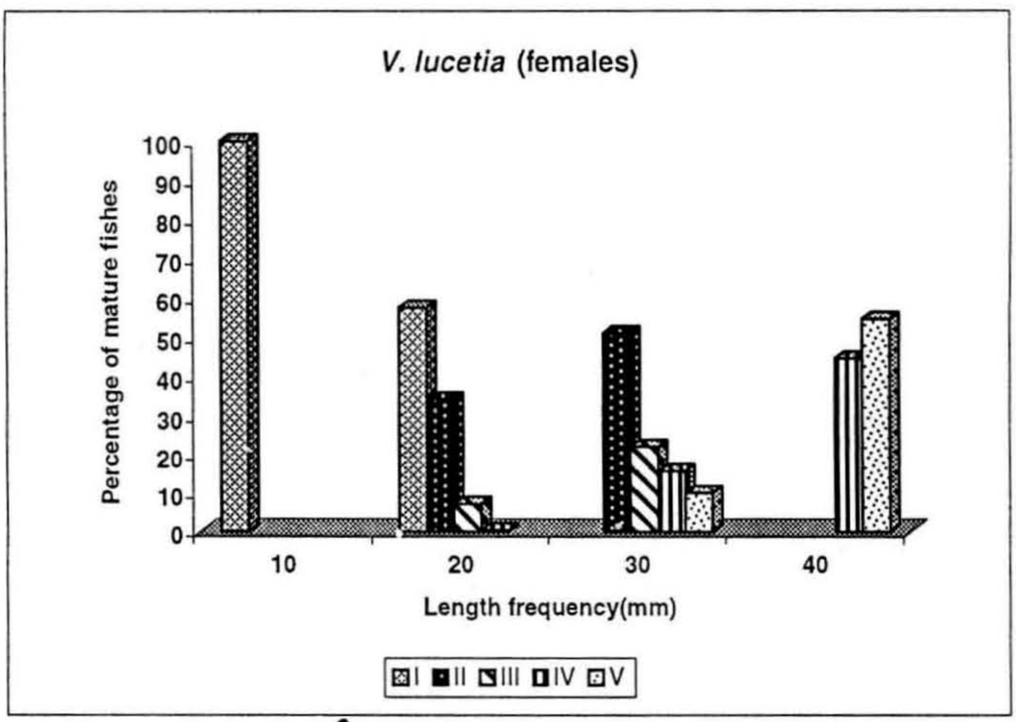


Figure 6.6 Length frequency distribution of different stages in females

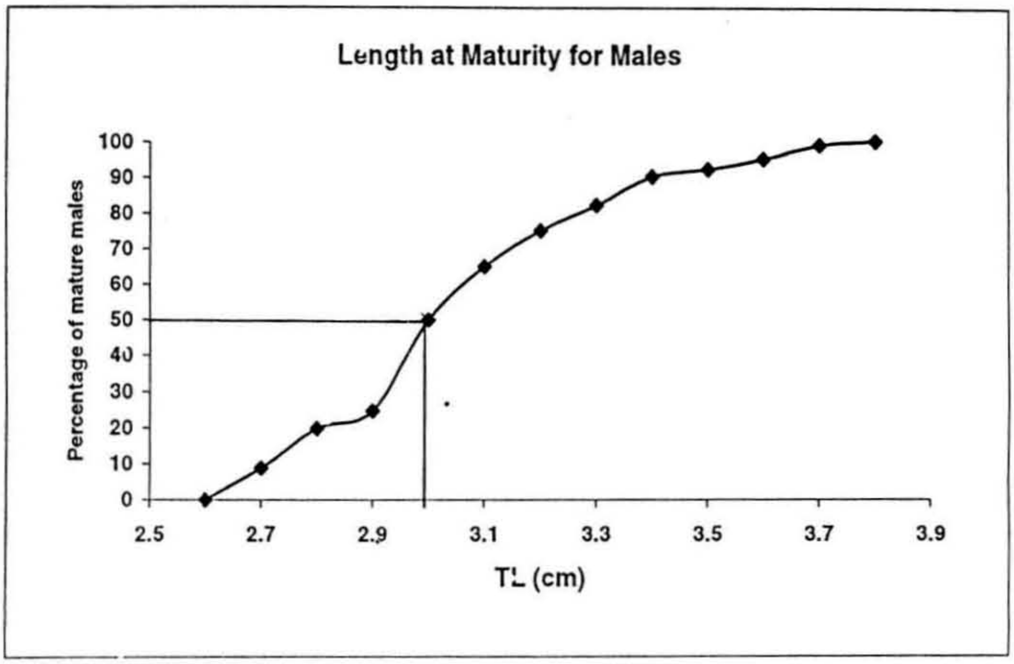


Figure 6.7 Length at first maturity for Males of the genus *Vinciguerria*

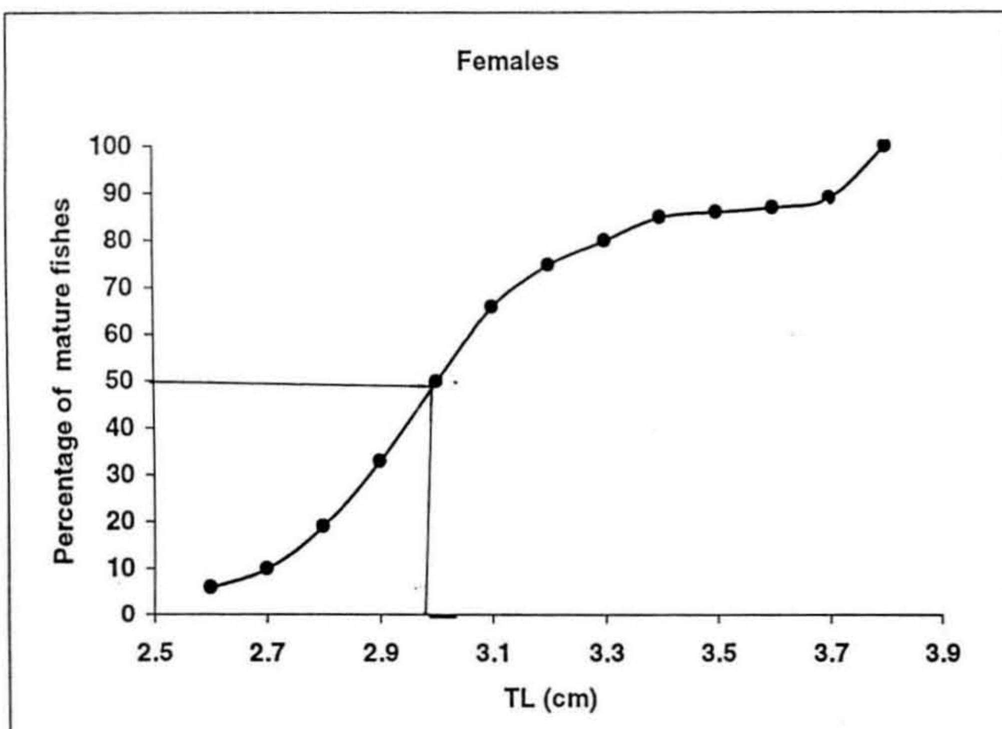


Figure 6.8 Length at first maturity for females of the genus *Vinciguerria*

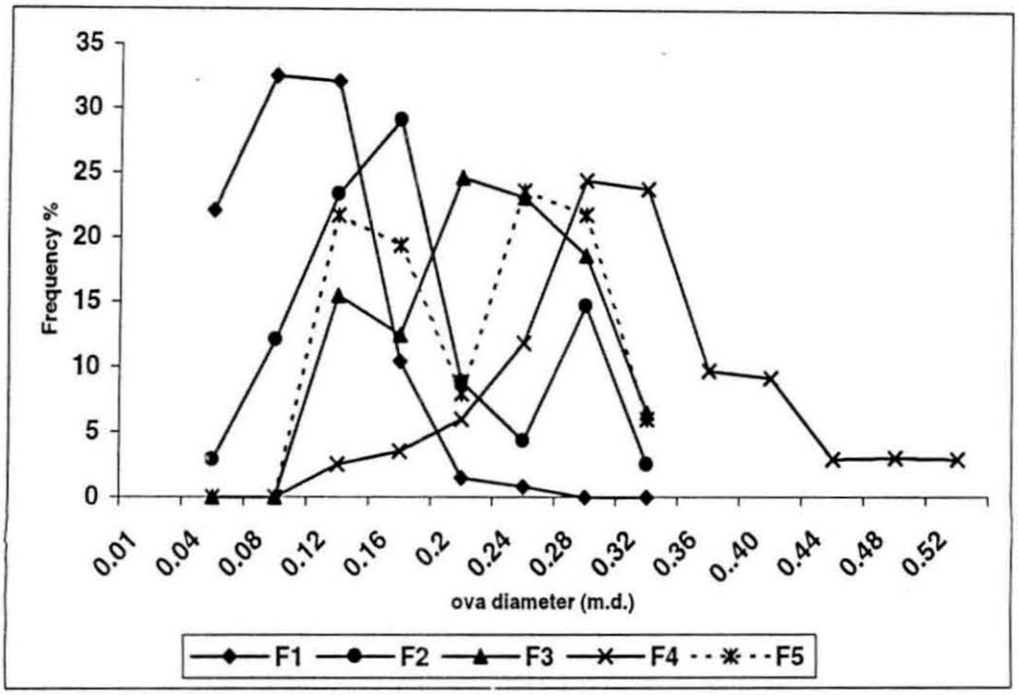


Figure 6.9 Ova -diameter for the genus *Vinciguerria*

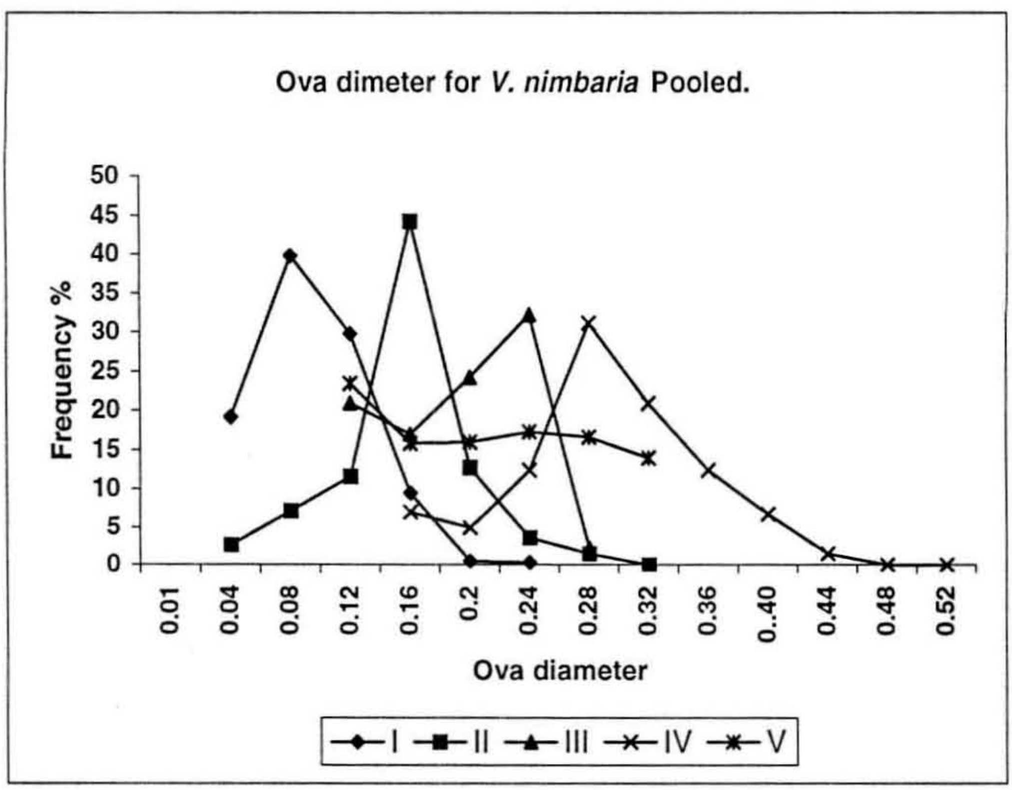


Figure 6.10 Ova -diameter for *V. nimbaria* pooled.

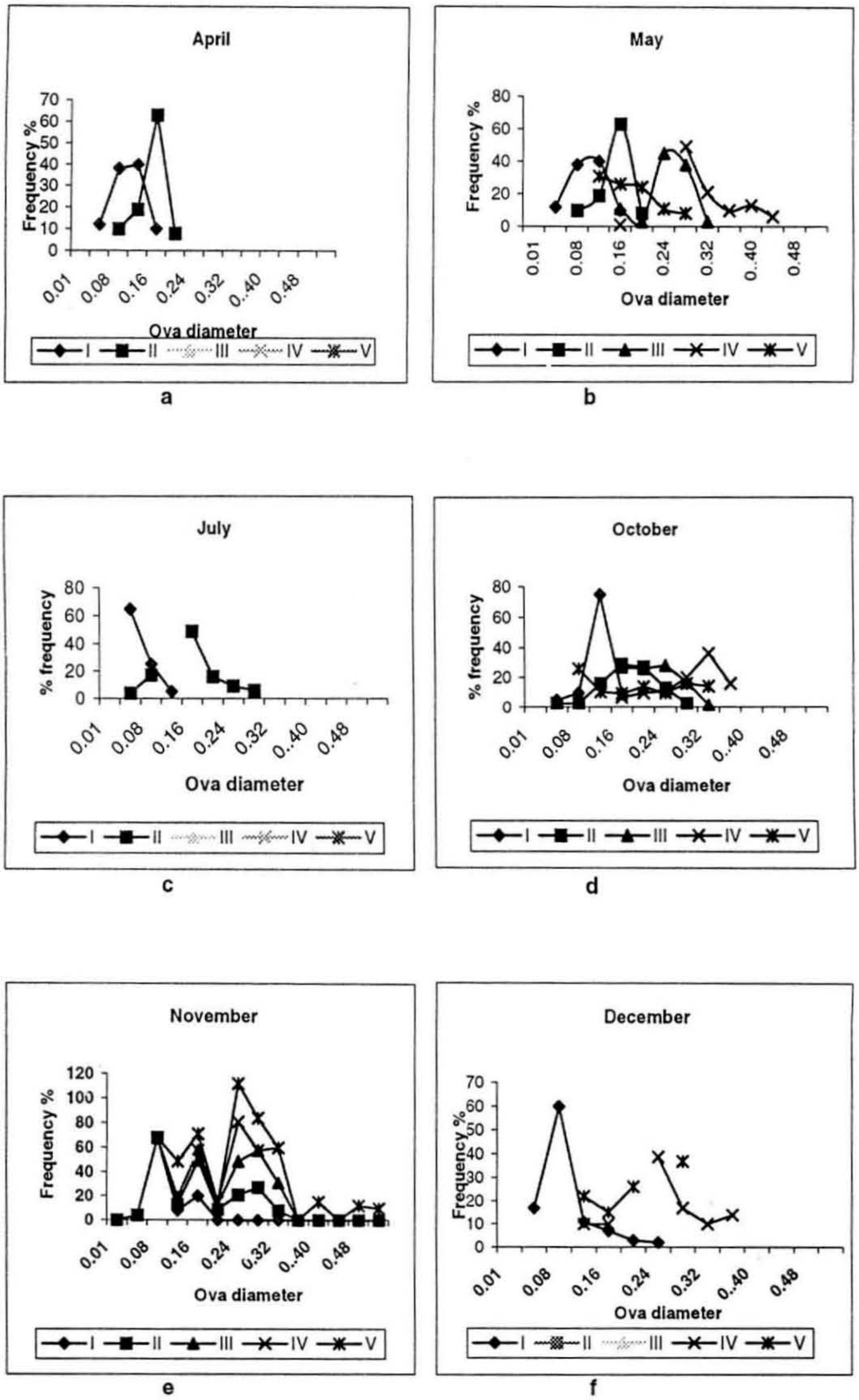


Figure 6.11 Ova -diameter for *V. nimbaria* at different months.(a-f)

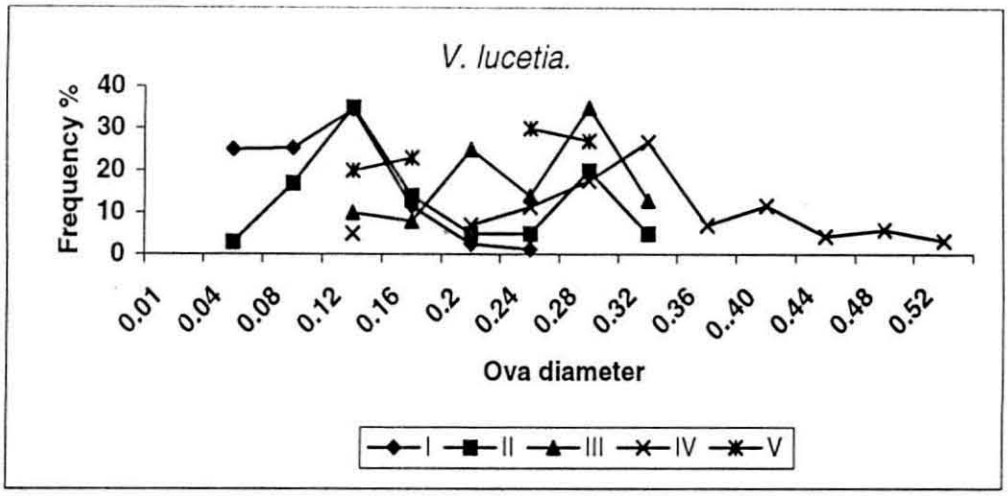
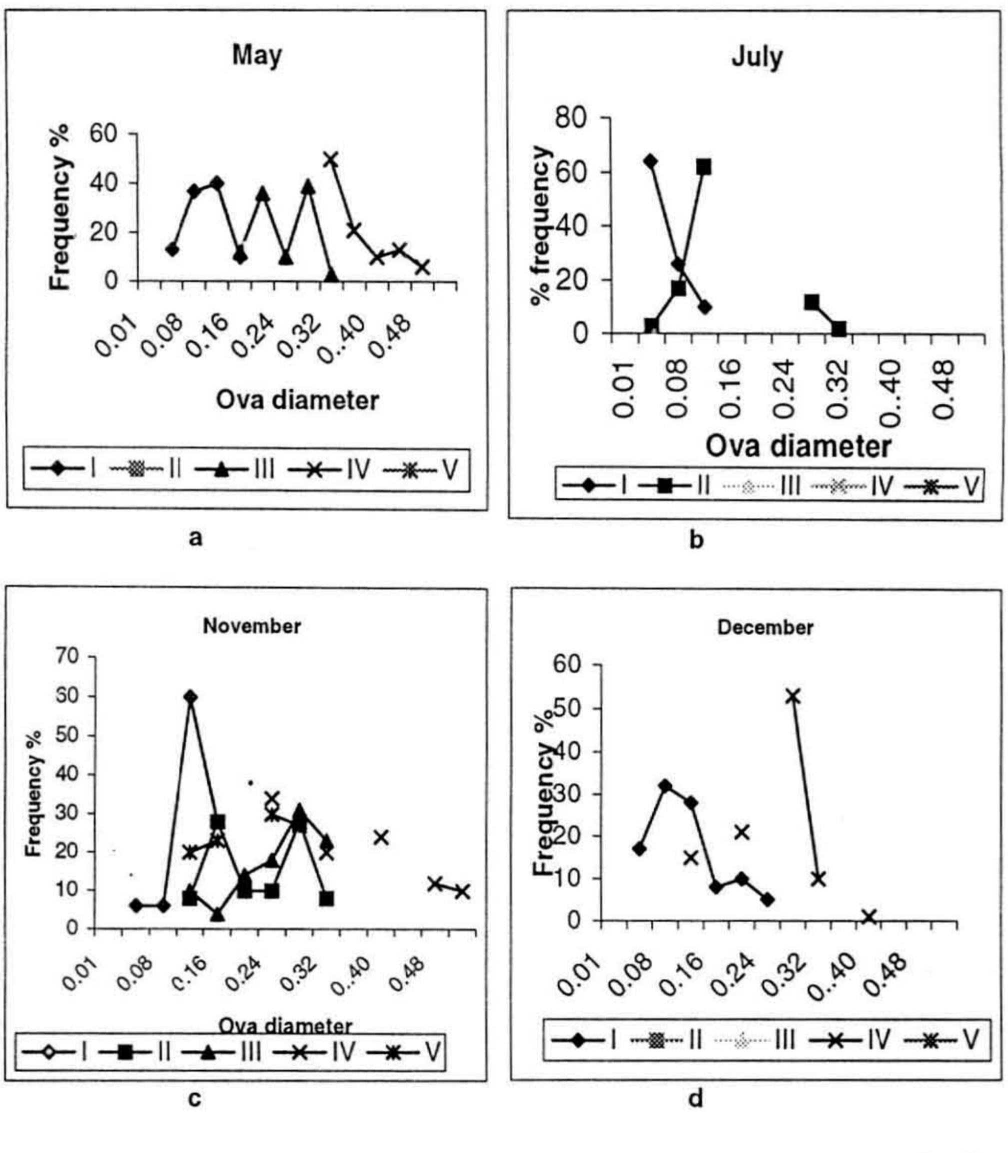


Figure 6.12 Ova -diameter for *V. lucetia* Pooled



a b c d

Figure 6.13 Ova -diameter for *V. lucetia* at different months (a-d)

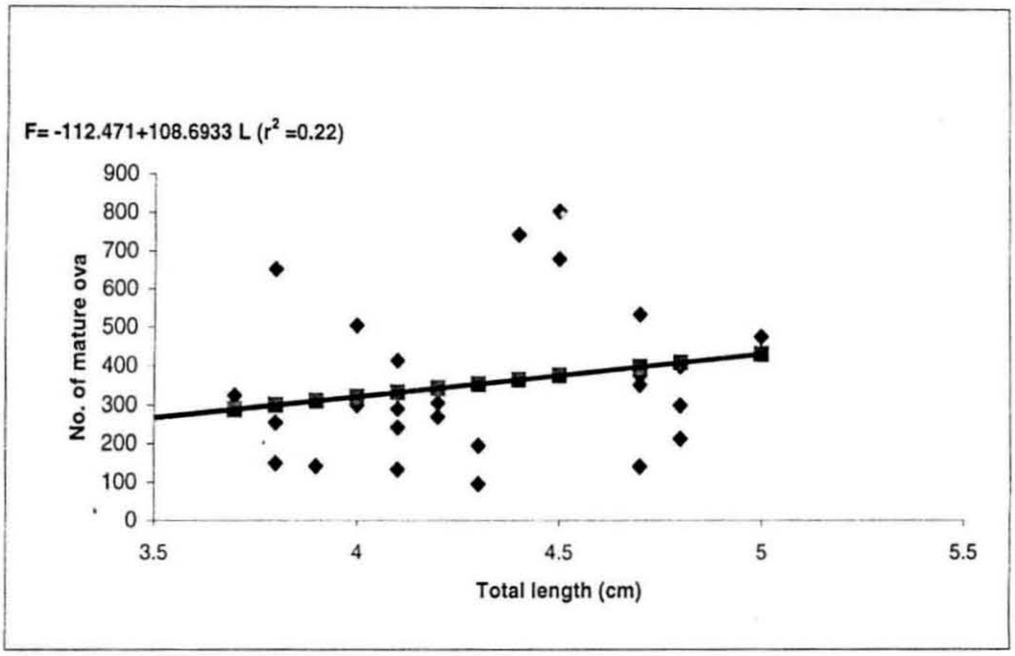


Figure 6.14 Plot of values of fecundity against total length in *V. nimbaria* and fitting linear relationship

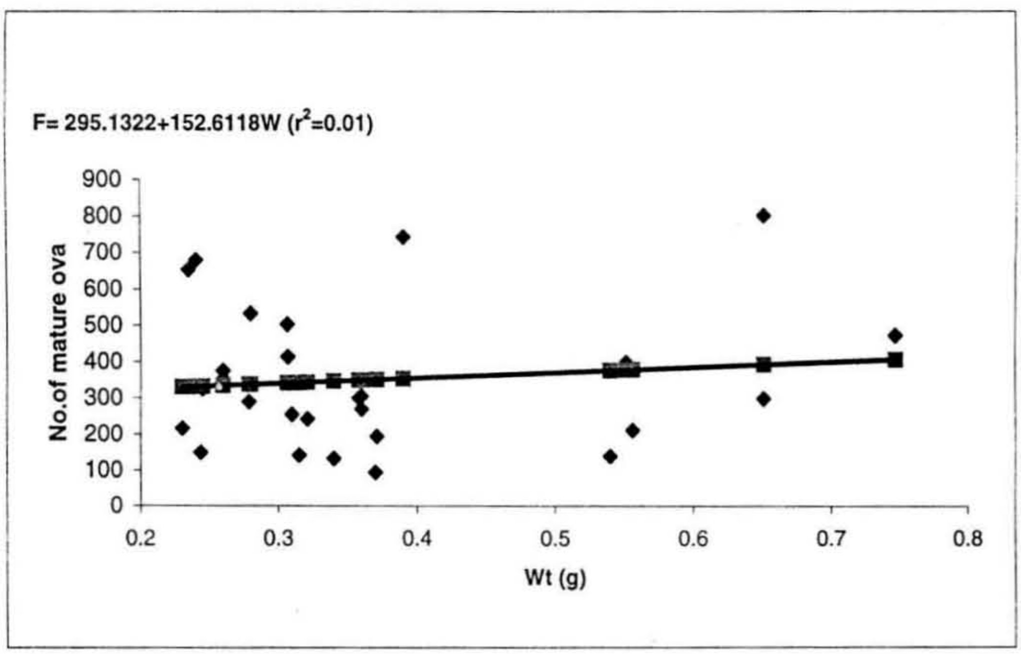


Figure 6.15 Plot of fecundity against weight in *V. nimbaria*, fitting a linear relationship

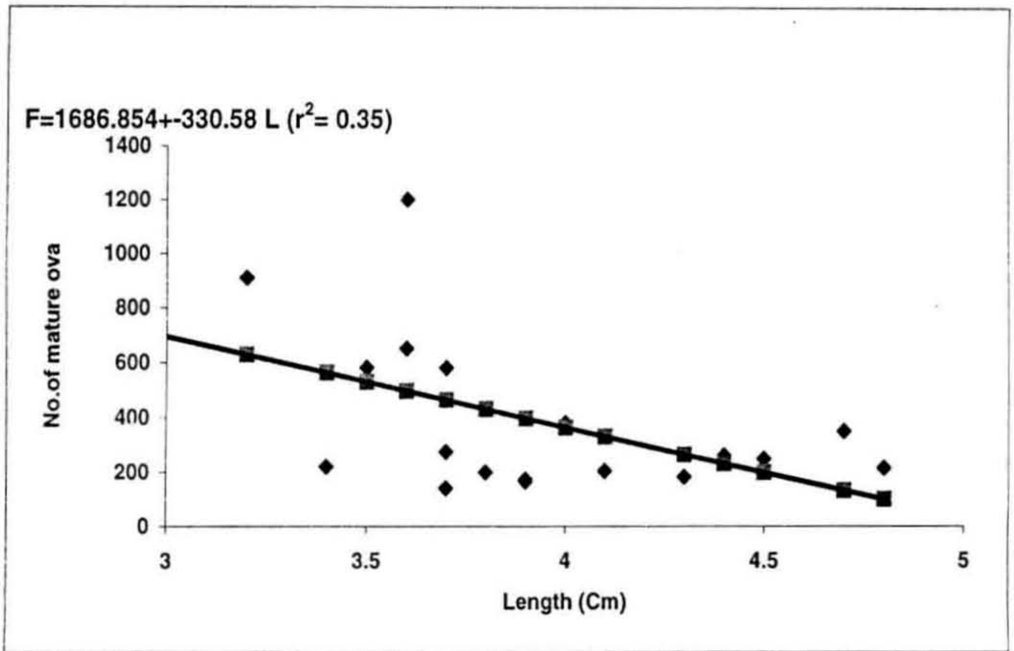


Figure 6.16 Plot of estimated values of fecundity against in Length in *V. lucetia.*

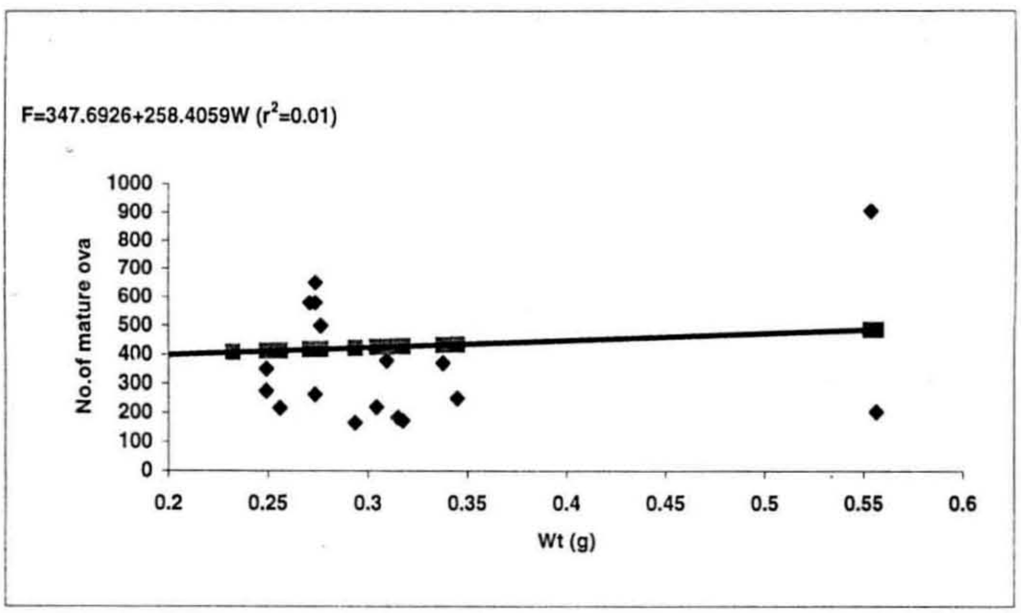


Figure 6.17 Plot of fecundity against total weight and fitting linear relationship in *V. lucetia.*

0.28. In November at stage I the mode was at 0.12 ,at stage II was 0.16 and 0.28, and in stage III was at 0.20, stage IV was at 0.24 and at stage V was 0.25.

According to Oven (1976), the spawning is continuous and intermittent in both the species. In *V. lucetia* it has been noticed despite a distinct portion of eggs ready to be spawned another portion of oocyte is being formed.

The maximum mean Gonadosomatic index for *V. nimbaria* was recorded in May, November and December during the period of increased spawning. The minimum goandosomatic index in *V. nimbaria* varied from values 1-7.59 , average was 3.85 The mean values of *V. nimbaria* varied from 5.75-13.74 with the average at 8.61. (Table 6.1) The maximum mean Gonadosomatic index for *V. lucetia* was recorded in July, November and December during the period of increased spawning. The minimum goandosomatic index in *V. lucetia* varied from values 1.28-3.57 , average minimum value was 2.90. (Table 6.2).

The overall sex ratio of both species was close to 1. The percentage of males and females and the number of sampled individuals of each sex by length group for the various months are as shown in the Table 6.5 for *V. nimbaria* and Table 6.6 for *V. lucetia*.

The fecundity in *V. nimbaria* varied from 215-805 with a mean at 510 eggs/ g. The fecundity in July was 805 and that in October 536 indicating the spawning period in *V. lucetia* the fecundity was highest at July (882 eggs). The absolute fecundity ranged from 180-882. The relative fecundity in *V. nimbaria* ranged from 666.11 to 1925 In *V. lucetia* the relative fecundity ranged from 571 to 3385

The data were analysed to fit regression lines of absolute fecundity on total length; absolute fecundity and total weight in both the species. The scatter plots for fecundity and total length and fecundity and weight in *V. nimbaria* are shown in Figure 6.14 and Figure 6.15. The scatter plots for absolute fecundity and total length and absolute fecundity and weight in *V. lucetia* are shown in Figure 6.16 and Figure 6.17.

Table 6.1 Gonadosomatic index at different months (*V. nimbaria*)

Month	TL	S.L	Body weight(g)	Gonad weight(g)	Min.	Mean
April	2.8-4.6	2.4-3.7	0.07-0.38	0.01-0.04	4.47	11.27
May	2.0-5.0	1.7-4.2	0.03-0.74	0.005-0.02	3.71	6.575
June	2.7-3.9	2.3-3.3	0.10-0.20	0.02	7.59	13.74
July	2.0-4.7	1.6-4.0	0.03-0.50	0.003-0.02	1	3.76
October	2.2-4.7	1.7-4.0	0.10-0.28	0.004-0.01	2.5	5.75
November	1.9-4.8	1.5-4.0	0.02-0.55	0.003-0.02	4.11	10.09
December	2.9-4.8	2.4-4.0	0.10-0.55	0.005-0.03	3.57	9.12

Table 6.2 Gonadosomatic index at different months (*V. lucetia*)

Month	TL	S.L	Body weight(g)	Gonad weight(g)	Min.	Mean
May	2.6-4.7	2.0-4.0	0.09-0.55	0.004-0.02	1.28	2.85
July	2.5-3.0	1.9-2.5	0.04-0.11	0.006-0.02	3.33	11.24
November	2.9-4.4	2.4-3.6	0.1309-0.3393	0.005-0.02	3.41	10.2
December	3.7-4.8	3.2-4.0	0.2490-0.5564	0.009-0.02	3.57	6.06

Table 6.3 Absolute fecundity (AF) and relative fecundity (RF) (*V. nimbaria*);

Months	TL	TW	Gonad weight(g)	Stage	Fecundity	
					Absolute	Relative
May	40	0.358	0.02	IV	300	837
	48	0.6513	0.02	IV	300	460
	38	0.3099	0.01	III	255	822
	50	0.7469	0.02	IV	475	635
	37	0.2446	0.01	III	325	1328
Average					**331**	**816**
July	45	0.6513	0.01	IV	805	1236
October	44	0.39	0.03	IV	744	1908
	47	0.28	0.01	III	533	1904
	47	0.26	0.01	III	352	1354
	47	0.26	0.009	III	375	1442
	45	0.24	0.008	IV	680	2833
Average					**536.8**	**1888**
November	34	0.23	0.02	IV	216	939
	43	0.3711	0.01	IV	195	525
	48	0.5518	0.01	IV	399	723
	38	0.243	0.007	III	149	613
	41	0.3211	0.01	IV	242.5	755
	42	0.36	0.02	V	306	850
	43	0.37	0.01	IV	95	257
	47	0.54	0.01	V	141	261
	42	0.36	0.006	IV	270	750
	41	0.34	0.01	IV	133	391
Average					**214.65**	**666**
December	48	0.5564	0.02	IV	213	383
	39	0.3151	0.01	III	142	451
	41	0.2789	0.01	IV	290	1040
Average					**215**	**624**

Table 6.4 Absolute fecundity (AF)and relative fecundity (RF) (*V. lucetia*)

Months	TL	TW	Gonad weight(g)	Stage	Fecundity	
					Absolute	Relative
May	37	0.2762	0.01	IV	275	690
	47	0.5531	0.02	IV	350	633
	40	0.3042	0.01	IV	380	1249
					335	**857**
July	36	0.2734	0.02	IV	1200	4389
	30	0.249	0.02	IV	1100	4418
	35	0.2734	0.02	IV	580	2121
	36	0.249	0.02	IV	650	2610
Average					**882.5**	**3385**
November	37	0.2707	0.02	IV	580	2143
	28	0.098	0.01	III	500	5102
	32	0.198	0.01	IV	910	4596
	41	0.3176	0.01	IV	204	644
	40	0.2936	0.01	V	372	1267
	44	0.3093	0.01	V	262	847
	45	0.3376	0.02	V	250	741
Average					**440**	**2191**
December	48	0.5564	0.02	V	216	388
	39	0.3151	0.02	V	173	549
	37	0.2734	0.02	IV	140	512
	43	0.3449	0.02	IV	183	531
	39	0.249	0.02	IV	166	667
	38	0.256	0.02	IV	200	781
Average					**180**	**571**

Table 6.5 Sex ratio for *V. nimbaria*

Month	Male(%)	Female(%)	M:F
April	60.87	39.13	1.00:0.64
May	54.10	45.91	1.00:0.85
June	50.00	50.00	1.00:1.00
July	44.29	59.71	1.00:01.35
October	51.79	48.21	1.00:00.93
November	46.75	53.25	1.00:01.14
December	53.85	46.15	1.00:00.86

Table 6.6 Sex ratio for *V.lucetia*

Month	Male(%)	Female(%)	M:F
May	33.33	53.33	1.00:1.60
July	37.50	62.50	1.00:1.67

The relation between the total length , weight and the absolute fecundity was analysed by regression and was observed that there was no relation between fecundity and total length and fecundity and total weight because of very low r^2 values in both the species studied as shown in Table 6.7.

Table 6.7 Relation between fecundity (F) and total length (TL,cm) and total weight (TW,g) of *V. nimbaria* and *V. lucetia.*

	Regression equation	r^2
V. nimbaria	F= -112.471+108.6933 L	0.22
	F= 295.1322+152.6118 W	0.01
V. lucetia	F=1686.854+330.58L	0.35
	F=347.6926+258.405 W	0.01

6.4 Discussion :

In both *V. nimbaria* and *V. lucetia* the sex ratio was close to 1. The sex ratio varied with length for both species.

Spawning in *Vinciguerria* was from November to December although ripe and spent females collected in December indicated that the spawning season of this species continues until early summer. The results are the same as reported in *Maurolicus muelleri* (Light fish). The mid water fish Myctophids in temperate and subtropical water generally spawn from late winter to summer . (Fait, 1960; Odate and Ogawa , 1961; Halliday, 1970; Goodyear *et al* .,1972; Clarke,1973; Gjosaeter *et al.*, 1977; Karnella and Gibbs; 1977, Okyama, 1971; Clarke 1982). Clarke (1973) postulated that reproductive cycles in midwater fishes were timed to coincide with the spring bloom and the consequent increase in zooplankton abundance. There is a high abundance of plankton available later in the spring. This possibility is supported by Okiyama (1971) who found that early post larva of *M. muelleri* can directly take the larger and much advanced organisms. (Okiyama, 1971) of the plankton.

Although the data are limited , fecundity in mid water species including Photichthids have been described by Gjosaeter and Kawaguchi(1980);Kawaguchi and Mauchline (1982). The fecundity of *V. nimbaria* and *V. lucetia* described here compares very closely with that reported by Menon *et al.,* 1996, suggesting that the fecundity of these species show little latitudinal difference. Prosch (1991) found that the fecundity varied from 161-738 with a mean of 334 eggs/g. The present results agree with the above findings.

The sex ratios for the species studied were found to be close to 1. The present results agree with earlier findings by Clarke (1983) who reported that the midwater fishes off Hawai were found generally to exhibit a 1:1 ratio of females to males with some exceptions particularly among larger Myctophid species where females were either more abundant or larger than males. Factors such as species size (Clarke, 1983), depth distribution (Badcock and Merett, 1976) and differential avoidance of nets (Klingheil, 1978) may have accounted for the bias towards females in this stage among Myctophids. In the present study it was observed that at certain months the females were more than the males in both the species studied. This can be attributed to species size, depth distribution and differential avoidance of nets.

The maturity ogive was 3.0. The present results in genus *Vinciguerria* are in agreement with that of findings of Menon et al., (1996). In *V. lucetia* the results of Andrianov and Bekker (1989) showed the specimens of both sexes to the length of 23mm were immature. Among fish of 23-26mm, maturing fish constituted a small part . The males and females of this species begin to mature at a length of about 26mm. Among mature specimens, fish at maturity stage II and final maturity stages prevailed.

As in the gonads of females of the species examined, portions of mature eggs or a separate group of oocytes in the vitellogenesis phase were found and a quantitative estimation of their portion fecundity (i.e., absolute number of eggs spawned at one time) was possible. Because of the well-known relation between the number of eggs produced and the size and weight of females , the relative fecundity (number of eggs per gm of body weight) seems a better indicator. The absolute fecundity was estimated by counting the total number of ova in both the lobes of ova in stage III and IV . Relative fecundity was defined as the number of eggs per gram of body weight The relative fecundity in *V. lucetia* was found to be high as reported by Andrianov and Bekker (1989). It should be added that the values of relative fecundity in these species prove their high reproductive ability. There was no correlation between the absolute and relative fecundity of both the species examined.

The presence of fully vitellogenic oocytes indicates that maturation is in progress. At late maturation and at the onset of spawning estimated the Gonado somatic index to be in the range of 15-18%. Comparisons may be based by difference in the area investigated (stock dynamics due to differences in life history difference in time (stock composition possibly influencing potential fecundity) and also by differences in methods used in the fecundity analysis . Variations in the fecundity in present study and the previous studies may be due to size distribution, exploitation level, environmental factors and of course the possibility of two different population with different oocyte production level. The relation between fecundity and total length and total weight was calculated by regression analysis.. The regression analysis showed no difference between the fecundity and total length and fecundity and the total weight in both the species studied. Because of very low r^2 values. The apparent absence of correlation between fecundity and total length and fecundity and total weight as revealed by poor r^2 values could be due to the random variations in fecundity.

The present results indicate that the spawning period is from November to December, and that they spawn in a single batch. Fecundity of *Vnimbaria* ranged from 215-805 eggs and that of *V lucetia* ranged from 180-882 eggs.

Chapter - VII

Trophic Relations

7. TROPHIC RELTIONS

World wide the family Photichthyidae is represented by 8 genera and 21 species. The genus *Vinciguerria* is a major component of the mesopelagic icthyofauna in the DSL (Menon *et al.*, 1996) The genus *Vinciguerria* and family Sternoptychidae of the DSL are found to play a major role in the trophic relations in the Oceans. They are seen to form prey for the commercially important fishes like skipjack and tuna and other fishes.

The first trophic guild contains the piscivores, like the skipjack and yellow fin tuna and other fishes belonging to other families. The food of tunas consists of mainly micronekton and euphausids. (Blackburn, 1965; Dragovich and Potthoff, 1972; Legand et al 1972). According to Alverson (1963) and Legand *et al*, (1972) *Vinciguerria* is eaten significantly by tunas. According to the above authors and the present work shows that the genus *Vinciguerria* is known to exhibit diurnal migrations from 600-1000m during day to surface 100 m at night,for mainly the purpose of feeding , but the genus *Vinciguerria* are within the vertical range of tunas in the day time as they mainly feed only during day. Dragovich and Potthoff (1972), reported large numbers of *Vinciguerria nimbaria* in the stomachs of skipjack and Yellow fin tuna. The family Gonostomatidae (Photicthyidae) was the most important forage item for both species in terms of volume. Rentjes and King (1953), stated that food items that rank high in volume and high in frequency of occurrence are important food at the time and in the area sampled. Using the above criteria *V. nimbaria* may be considered to be important in the food chain of skipjack and yellow fin tunas for the given time and area.

The yellow fin Tuna (*Thunnus albacares*) were found to feed on Sternoptychidae and skipjack *Katsuwonus pelamis* fed on Sternoptychidae and *V. lucetia* (Photichthyidae). Alverson (1963) reported that the second ranking forage item for skipjack from the East Pacific was a small bathypelagic fish *V. lucetia* which comprised 10% of the total volume. Dragovitch and Potthoff (1972) analysed the stomach contents of the tuna fished by the US research vessel '***Undaunted***' during two cruises made on the west coast of Africa from 15° S to 5°N in 1968. During the first cruise made in the warm season from February to April where large numbers of *V. nimbaria* were seen in the diet of both species of tuna so that the family Gonostomatidae (now Photichthyidae) was the most important forage item for both species in terms of volume. During the second cruise from September to November there were no records of *V. nimbaria.* They concluded that *Vinciguerria* may contribute very significantly to the diet of surface tuna but in limited areas and according to the season.

Tuna are visual predators and must be together with their prey in the upper layers during the day. Since *V. nimbaria* has been recorded as a very common prey for surface tuna atleast in certain areas and seasons , there should be schools in the upper layers during the day.

Gorelova *et al.*, 1987 worked on the feeding habits of flying fishes in the Atlantic ocean. They reported that the main food items found to be present were crustacea, siphonophore, chaetognath and mollusks from the surface layers and Vinciguerria was also found to be abundant. Ramirez, 1986 reported that the oceanic Bryde whale fed almost only on *V lucetia*

The present study and studies by Menon *et al.*, (1996) have shown that there is a part of the population which continues to feed on the surface even during the day. According to Marchal and Lebourges (1996) at night fish concentrate at or below the thermocline in large elongated aggregations that may extend for tens of nautical miles. At dawn atleast some of the fish ascend quickly and start schooling very close to the surface. They stay in the upper layers during the morning. Around the middle of the day they move down to the bottom of the thermocline where they feed actively on copepods. Tuna exploit this behaviour and catch their prey during early morning and late afternoon. The present observations on the genus *Vinciguerria* agree with this.

The next levels in the trophic guild are the zooplanktivores. The present studies and studies on food and feeding of *V. nimbaria* and *V. lucetia* by Legand and

Rivaton (1969); Legand *et al.*, (1972); Roger (1980) Ozawa *et al* (1977); Clarke (1978); Kawamura and Hamaoka (1981) and Kalnina and Shevchenko (1984), have shown that *V. nimbaria* and *V.lucetia* prefer copepods, ostracods also feed on amphipods, euphausids, shrimps and chatognath. *Polyipnus* species belonging to family Sternoptychidae fed on copepods , decapod larvae and shrimps *.A. hemigymnus* feeds on calanoid copepods, small fishes etc (Badcock , 1984)*.A. sladeni* feeds on copepods (Hart, 1973). *A. affinis* feeds on copepods and ostracods and larger ones feed on Euphausids, salps and chaetognath. (Badcock, 1984). Hopkins and Baird 1973 and Baird and Hopkins 1981 have shown that there is an active feeding during the day time by non migratory sternoptychids. Others have reported daytime or a cyclic feeding in Myctophids (Samyshev and Shetinkin, 1971; Clarke 1978) Gonostomatids (Dewitt and Calliet ,1972) Caridean and mysid shrimp (Roe, 1984;Nishida *et al* ., 1988)

The zooplankton of the DSL which formed the food for the mesopelagic fishes and form a important link between the diatoms , small phytoplankton and larger predators such as fish form the next trophic guild.

The copepods dominate the Zooplankton occurring sometimes in wide swarms. Although copepods consume diatoms to a very great extent they may also prey on several kinds of organisms flagellates, ciliates, dinoflagellates coccolithphores, foraminiferans and radiolarians, chaetoganaths, fish eggs and larvae as shown by several workers (Weisse ,1983; Stoecker and Capuzzo, 1990; Robertson, 1983; Tiselius, 1989; Wickstead, 1959; and Yen 1987) .They in turn form a major food item for the genus *Vinciguerria* including other mesopelagics. Copepods are vital links between diatoms and small fish, Photichthyidae and deep sea shrimps form a major part of the diet of the larger predators of the mesopelagic such as tuna etc.

Vinogradov (1962) reported that the ostracods include animals with varied diets. Their gut contents were found to have remnants of radiolarians , foraminiferans , crustaceans and chaetognath. Ivlev (1961) observed that ostracods are generally predatory with copepod remains particularly predominant in the stomach. However, detritus and diatoms also frequently are present and may be trapped by the sticky secretion of the marginal glands of the carapace or by the mandibular. The main diet of ostracods is of copepods and that they are able to feed on the prey of equal size equal to its own length. Cannon (1940) showed that ostracods were predacious on sagita, copepods and even on fish larvae.

Kane (1963) suggested that the amphipod *Parathemisto* might take dead as well as living tissue. Siphonophores and medusae as a major part of the diet of amphipods. They in turn serve as food for the fish larvae and form forage for the mesopelagics. The amphipods in the DSL are found to play an important role in the food chain of mackerels and herrings, tunas and seals.

The chaetognaths are carnivore feeding on smaller organisms like copepods, siphonophores, medusa, euphausiids, fish eggs and larvae playing a key role in the food cycle and ultimately help in the increase of fish production as these are fed by bigger carnivorous forms and fishes.

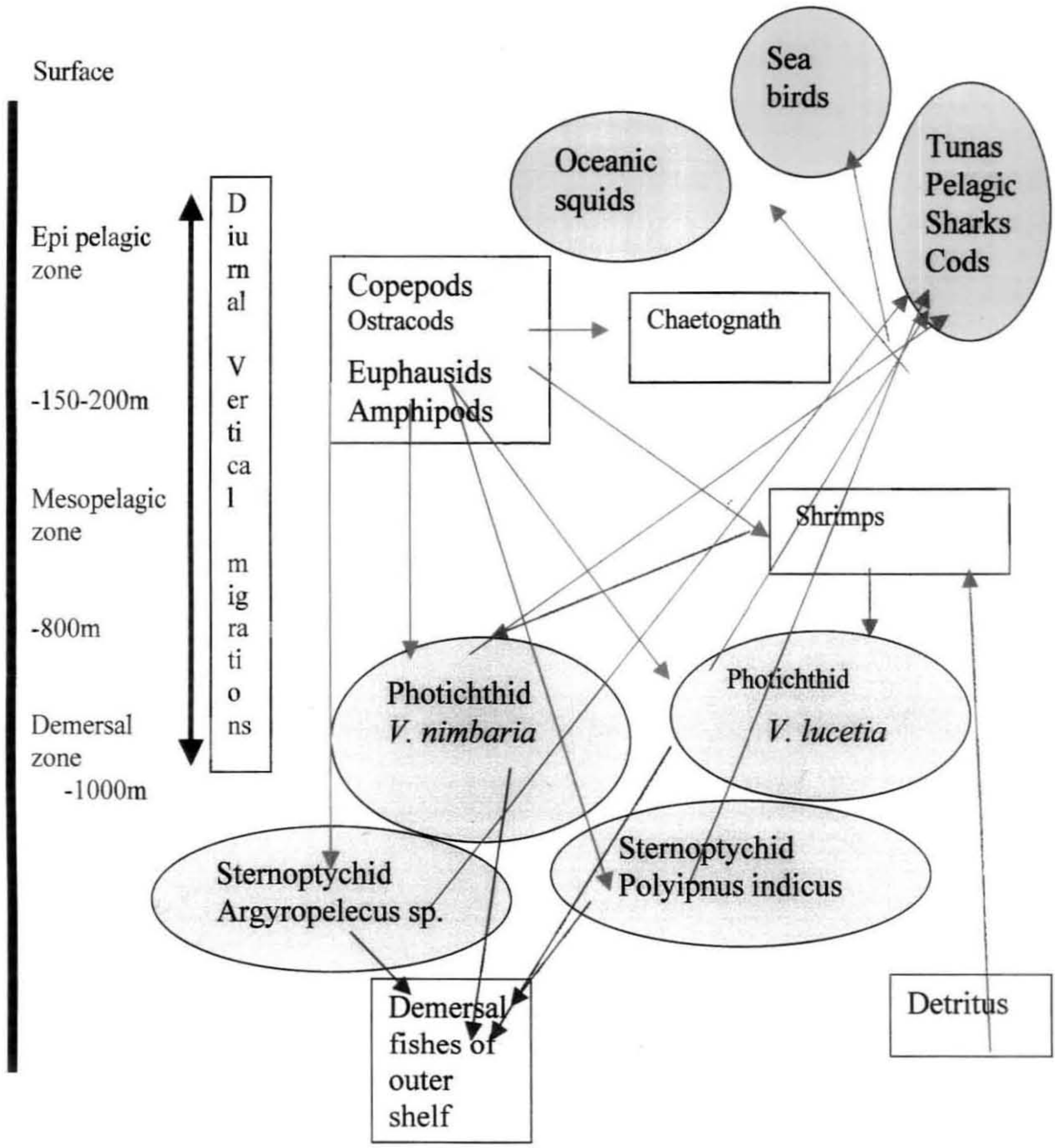
The megalopa larvae also are links in the food web by serving as food for the plankton like copepods and ostracod. They feed on detritus and other phytoplanktonic organisms. The pteropods are essentially herbivorous plankton feeders grazing on dinoflagellates and diatoms of suitable size and shapes. Some pteropods can use nanoplankton flagellates. The feeding is a combination of ciliary transport with mucous secretion. Not only phytoplankton but also occasionally foraminifers and radiolaria may also be taken. The pteropods are inturn eaten by the decapod larvae.

The euphausiids of the DSL may be largely carnivorous (eg, *Nematobrachion*) but some species of *Nematoscelus* showed detritus material which contained some degenerated chlorophyll. Some species including *E. pacificia* , *Thysanoerra longipes*, *Tessarabrachion oculatus* and *Thysanopoda triccuspidata* feed mainly on surface layers at night and show a fare proportion of chlorophyll in the gut. Fischer and Goldie (1959) confirmed that detritus, dinoflagellates diatoms, crustaceans including copepods and Eucarida were taken. Mauchline (1966) reported that molluscs, amphipods, large zooplankton, globigerena were all consumed but copepods formed the dominant animal food.

Thus it can be concluded from the above review that the genus *Vinciguerria* and the family Sternoptychidae play a important role in trophic relations in the oceans. The Figure 7.1 shows this relationship diagrammatically.

Figure 7.1.

TROPHIC RELATIONS OF FAMILY PHOTICHTHYIDAE AND STERNOPTYCHIDAE



SUMMARY

The salient findings of the present study are as follows:

- The families Photichthyidae and Sternoptychidae contributed to 29.31% of the nektonic biomass of the DSL. The area covered was from Lat.6°02'-21°00'N and Long.69°00'-73°00'E which was covered in 12 cruises. Of the two families studied family Photichthyidae contributed 97.2 % and family Sternoptychidae contributed 2.7%.

- During the study period 3 species of the family Photichthyidae i.e., 2 species of genus *Vinciguerria* (*V. nimbaria, V. lucetia*) and one genus *Icthyococcus* with species *I.ovatus* was encountered in the Eastern part of the Arabian Sea.

- The following species of the family Sternoptychidae was encountered in the Indian EEZ during the study period: *Argylopelecus hemigymnus, Argyropelecus affinis ,Argyropelecus sladeni and Polyipnus indicus* .

- The species of the family Photichthyidae show diurnal migrations, seen during day at 600- 1000m depths and at 50-200m depth during night while the species of the family Sternoptychidae i.e., *Argyropelecus affinis* and *Argyropelecus hemigymnus* showed very little diurnal migrations and *Argyropelecus sladeni* and *Polyipnus indicus* showed no diurnal migrations as these fishes were observed at depths from 500m to 650m both during day and night.

- *V. nimbaria* (family Photichthyidae) is abundant in the Arabian sea when compared to *V. lucetia* (family Photichthyidae) and *I.ovatus* (family Photichthyidae). Abundance of *V. nimbaria* was reported from Lat.15°N-18°N in the north west coast of India. *V. nimbaria* and *V. lucetia* do not show much variation in their distribution and vertical migration.

- The Genus *Icthyococcus* was represented by the species *I. ovatus*, which occurred at Latitudes 10°00N, 6°09'N and 7°59' N in the west coast.

- The total number of specimens of the family Sternoptychidae recorded during day was 199 numbers and at night was 31 numbers. The highest catch of family Sternoptychidae recorded in a single haul was 47 numbers at Lat.9°30'N and Long.75°20'E. The species of the family Sternoptychidae occurred more during day hauls in the south west coast of India.

- The estimated biomass of the family Photichthyidae was recorded during March (1507 tonnes) and the lowest biomass was recorded at July (35 tonnes). In family Sternoptychidae the biomass in tonnes ranged from 0.49 to 1820 tonnes.

- The family Photichthyidae was abundant in the north west coast whereas family Sternoptychidae was abundant in the south west coast.

- The study on the taxonomy showed that the two species of the genus *Vinciguerria i.e., Vinciguerria nimbaria* and *Vinciguerria lucetia* (family Photichthyidae), species of the genus *Ichthyococcus* i.e., *I.ovatus* (family Photichthyidae) can be distinguished on the basis of the arrangement of photophores.

- The head photophores arrangement of the species in the genus *Vinciguerria* (*V. nimbaria* and *V. lucetia*) are similar i.e., the Symphysal (SO); Orbital (ORB); Opercular (OP); Branchiostegal photophores and Isthimian photophores. The body photophore counts i.e., the Lateral body photophores (OV and Lateral VA); Ventral body photophores (IV and ventral VA) and Anal to Caudal photophores (AC) differ for the species of the Genus *Vinciguerria.*

- Identification of genus *Argyropelecus* was done by the presence of a large triangular transparent plate in front of the dorsal fin and an abrupt ventral constriction between the trunk and tail and the genus *Polyipnus* was identified by the presence of a forked spine in front of the dorsal fin. In genus *Polyipnus* an abrupt ventral constriction between the trunk and tail was absent. During the study *Polyipnus spinosus* was considered to be a synonym to *Polyipnus indicus*.

- The common equation for the length weight relationship for *V. nimbaria* was estimated as

  $W= 0.00992839\ L^{2.81431017}$

- The common equation for the length weight relationship for *V. lucetia* was estimated as

  $W= 0.006483607\ L^{3.164497613}$

- The study on food and feeding showed that V. *nimbaria* and *V. lucetia* are typical zooplanktivores, feeding on copepods , ostracods, shrimps, euphausids, pteropods, amphipods, fish eggs and semi digested zooplankton. These fishes are nocturnal feeders. The food compositions of both the species are the same.During day these fishes are found at depths 600-1000m. Feeding was minimal due to non-availability of prey organisms at these depths.

- Specimens collected from different seasons and depths had different gut contents, which was directly proportional to the abundance of prey. Based on the samples collected during different time period it was observed that the fishes of the genus *Vinciguerria* feeds at 16.00 –22.00 hrs. with peak feeding from 21.00hrs to 22.00hrs.

- The spawning period for the genus *Vinciguerria* was from November to December. The length at first maturity for V. *nimbaria* and *V. lucetia* was estimated at 30 mm. The ova diameter studies for *V. nimbaria* indicated that they spawn in a single batch. The overall sex ratio of both species was close to 1.

- The fecundity of V. *nimbaria* was estimated at 215-805 eggs with a average observed fecundity of 510 eggs. In *V. lucetia* the fecundity estimated ranged from 180-882 eggs. The regression of fecundity on total length and total weight of *V. nimbaria* and *V. lucetia* showed that there was no relation between fecundity and total length and the fecundity and total weight because of the very low r^2 values.

- The study on trophic relations showed that the first trophic guild contains the piscivores, like the skipjack (*Katsuwonus pelamis*) and yellow fin tuna (*Thunnus albacores*) and other fishes belonging to other families. The food of tunas consists of mainly micro nekton and euphausids.The family Photichthyidae was the most important forage item for both species in terms of vclume. *V. nimbaria* may be considered to be important in the food chain of skipjack and yellow fin tunas for the given time and area.

- The genus *Vinciguerria* is known to exhibit diurnal migrations from 600-1000m during day to surface 100 m at night, for mainly the purpose of feeding, but the genus *Vinciguerria* are within the vertical range of tunas in the day time as the tuna mainly feed only during day. Yellow fin tuna (*Thunnus albacores*) fed on Sternoptychidae and skipjack *Katsuwonus pelamis* fed on Sternoptychidae and *V. lucetia* (Photichthyidae).

- The next levels in the trophic guild are the zooplanktivores. The present studies and studies on food and feeding of *V. nimbaria* and *V. lucetia* showed that they feed on zooplankton namely copepods, ostracods, amphipods, chaetognath and decapod larvae. *Argyropelecus hemigymnus* and *A. sladeni* feeds on copepods. *A. affinis* feeds on copepods and ostracods and larger ones feed on euphausids ,salps and chaetognath. *Polyipnus* species belonging to family Sternoptychidae fed on copepods and decapod larvae.

- The zooplankton of the DSL that form the food for the mesopelagic fishes are a important link between the diatoms, phytoplankton and larger predators such as fish. They form the next trophic guild.Copepods and other zooplankton like ostracods etc. are vital links between diatoms and small fishes of family Photichthyidae, family Sternoptychidae and other mesopelagic fishes and deep-sea shrimps thus forming a major part of the diet of the larger predators of the mesopelagic such as tuna etc.

➢ Thus it can be concluded from the above study that the genus *Vinciguerria* and genus *Icthyococcus* belonging to family Photichthyidae and the genus *Argyropelecus* and *Polyipnus* of the family Sternoptychidae play a important role in trophic relations in the oceans.

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